Benj. Ward Richardson Esq.

with Dr Snow's Comp.s

ON

NARCOTISM

BY THE

INHALATION OF VAPOURS.

BY

JOHN SNOW, M.D.

LICENTIATE OF THE ROYAL COLLEGE OF PHYSICIANS.

PARTS EIGHT TO SIXTEEN,

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ON

NARCOTISM BY THE INHALATION OF VAPOURS.

Part VIII.

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Before entering further on the subject of the administration of chloroform, it will be expedient to inquire what are the circumstances, if any, which forbid its use. And experience requires me to make the remark of this substance, which I made last year of ether,—that I know of no state of the patient, with respect either to age, constitution, or disease, which positively contraindicates the use of it, where it is required to prevent the pain of a severe operation, or, I may add, of one the patient greatly dreads. In making this statement, I must not be considered to be recommending the indiscriminate use of chloroform. On the contrary, I consider that everything connected with the patient should be taken into the account, and duly weighed, and the decision arrived at accordingly. And when I state that I have administered chloroform in almost every possible condition in which a patient could require an operation, it must not be considered that I have acted without discrimination, but rather, that going on gradually, and acting on previous experience, supposed objections have one by one vanished, and it has appeared that care in the mode of giving the vapour was the main guarantee, both of safety and success. This view of the subject is entertained by others as well as myself; for, it must be recollected, that I have never given chloroform or ether in an operation, without the concurrence of other medical men.

Chloroform acts more pleasantly, however, on some patients than on others; and we may therefore proceed to consider the circumstances which influence its mode of action. The period of life in which chloroform acts most pleasantly is childhood. In children under thirteen years of age it scarcely ever causes either mental excitement, or any of the struggling which is not unusual in adults just before insensibility ensues, and immunity from pain is obtained with less narcotism of the nervous centres than in older subjects, as I stated before. It is never necessary to carry the narcotism further than the beginning of the third degree in children, at which time I believe their eyes are always turned up; and very often it is not requisite to carry the effects of the vapour beyond the second degree. Indeed, I have seen a child look about it, with a smile on its face, in the middle of the operation of lithotomy.

In a paper which I read at the beginning of the year, I recommended ether for children, in preference to chloroform, on account of the action of the latter being extremely rapid in young patients; but with the apparatus I described in the last paper, the vapour of chloroform can be so diluted with air as to become as mild and gradual in its action as one pleases, and since I have had small face-pieces suited for infants, I have generally given chloroform, and have administered it to a great number of children,

from three weeks old upwards. But when the practitioner is only provided with a handkerchief or sponge, I still consider that the use of chloroform is not perfectly safe, and that ether ought to be employed.

As age advances, the action of chloroform, though equally safe and effectual, is less uniformly pleasant in appearance. In old age, indeed, there is frequently either groaning or a slight degree of stertor, not only during an operation, but even before it begins; so that the effect of the vapour, although quite as satisfactory to the patient, is less agreeable to the friends who may be looking on, than in young subjects. I have often exhibited chloroform in extreme old age, and always with the best effects: indeed, I consider that age is not a source of danger when care is taken. Old people are generally rather longer than others in recovering their consciousness, probably because, owing to their circulation and respiration being less active, the vapour requires a longer time to escape by the lungs. They sometimes do not perfectly recover their former state till twenty minutes or half an hour has elapsed from the conclusion of the operation.

The general condition of the patient as regards robustness, or the contrary, has a considerable influence on the way in which chloroform acts. Usually the more feeble the patient is, whether from illness, or any other cause, the more quietly does he become insensible; whilst if he is strong and robust, there is very likely to be mental excitement in the second degree, and rigidity of the muscles, and probably struggling in the third degree of narcotism. This action of the muscles generally occurs when they are well nourished, whilst in the cases in which they are flaccid, and probably pale, it is usually absent.

The special conditions termed diatheses, seem to have no regular influence over the action of chloroform, except the hysterical one, and this is apt to occasion a little trouble; for as soon as a patient who is subject to hysteria loses her consciousness, from the effect of the vapour, a paroxysm of the complaint is sometimes occasioned. This, however, can always be subdued by proceeding with the inhalation. But the hysterical state, in a few instances, returns, and becomes troublesome, as the effect of the vapour subsides. In two cases that I have met with, it continued for three or four hours. I saw one case, indeed, in which the hysteria lasted much longer, but it was kept up by the alarm of the practitioner in attendance, who was not well acquainted with the action of chloroform,—had given, I believe, an overdose in the first instance, and afterwards mistook the hysteria for the continued effect of the vapour. I was called upwards of thirty hours after the inhalation, when the anxious attendance on the young woman being discontinued, and some of the usual remedies for hysteria applied, she began to amend, but remained in indifferent health for some time. I believe that one or two cases of continued convulsions after chloroform and ether, related in the medical journals, were cases of hysteria. In trying to estimate how far the provocation of hysteria is a drawback from the benefits of chloroform, it must be remembered that the pain of an operation, and still more, perhaps, the anticipation of it, would cause an attack of hysteria in many patients; and I think the proper view to take of the subject is, that whilst a tendency to this complaint ought strictly to forbid the inhalation for amusement, which was at one time somewhat the fashion, it should not interfere with its use in a painful operation, or in any necessary operation, to which the patient cannot otherwise be induced to submit.

Persons subject to epilepsy are liable to have a fit brought on by inhaling ether or chloroform. This occurred in a young lady who had a tumor of the lower jaw removed by the late Mr. Liston, and took ether, but I was able to subdue the convulsions before the operation began, by continuing the vapour, and with chloroform, this, of course, could be more quickly accomplished. It was stated, in one of the foreign medical journals, that chloroform is so certain to cause a fit in epileptic persons, that it may be used to detect impostors pretending to be subject to this disease; but Dr. Todd, who has used chloroform with some advantage in the treatment of epilepsy, in King's College Hospital, has informed me that it does not always produce an

attack, even when carried to the extent of causing complete insensibility.

I may here mention a case, though not connected with a surgical operation, in which chloroform caused a recurrence of renal convulsions, from which the patient had been suffering:—A working man, aged about 35, had been in ill health for some weeks before I was called to him on Feb. 19, on account of his being found insensible on the floor. He had in some measure recovered when I arrived, but was in a state of partial stupor, which on the following day was increased, and accompanied with violent convulsions. There was œdema of the face and extremities, and his urine was albuminous, scanty, and of diminished specific gravity. He was bled from the arm, and took digitalis and potash, and on the 22nd, had quite recovered from the convulsions and stupor, and the urine was improved. On the 23rd, however, he became affected with delirium cum tremore, and in the evening I administered chloroform to him, having seen it apparently of service in two or three cases of this disorder. It no sooner began to take effect, however, than violent convulsions came on, of exactly the same kind as those with which he had been affected three days before, and accompanied with the same frightful distortion of the features. Although I did not deem it unsafe to continue the chloroform, I thought it more advisable to discontinue it, and to try the effect of opium. The chloroform having been left off, the convulsions almost immediately subsided, and in three or four minutes the patient was in his former state of delirium. He took twenty-five minims of tincture of opium, and the same dose three hours afterwards. He had a good night's rest, the next day was free from the delirium, and he gradually recovered his health. At the time the patient took the chloroform, there is no doubt that his blood still contained a certain amount of urea and other impurities, and the vapour seemed to act as an additional quantity of these impurities would have done, whilst opium had a different and beneficial effect.

Having noticed the general conditions of the patient, it remains to be inquired how far local disease interferes with the action of chloroform; but previously, the state of pregnancy may be noticed. I recollect two instances in which the patients were pregnant. One was that of a lady, about six months advanced, for whom Mr. Rogers removed some teeth. The chloroform had been recommended by her usual physician before I saw her. The other was a patient in St. George's Hospital, less advanced in pregnancy, on whom Mr. H. C. Johnson operated for the removal of a small fatty tumor. The result was quite favourable in both cases. The narcotism was carried only just to the third degree, and I think that care should be taken not to induce very profound insensibility in pregnancy.

Any affection of the lungs that would not prevent a surgical operation, would be no impediment to the administration of chloroform. I have exhibited it in a few cases in which there was evidence of crude tubercles, and in one case in which cavities existed, and the only result was, that the cough was generally relieved for a day or two afterwards. This has generally been the case also in chronic bronchitis, which has existed in a considerable number of patients. There is sometimes a troublesome fit of coughing at the commencement of the inhalation, when any pulmonary affection exists, but this soon subsides. I have not seen the least injury to the respiratory organs result from the use of chloroform in any instance.

I have already alluded to affections of the heart, and have little to remark now, except that chloroform, carefully administered, is less likely to be prejudicial than severe pain. The patients, however, should be attended to afterwards, and if the chloroform is followed by sickness and coldness, as happens in a few cases, warmth should be applied externally, cordials given, and, if necessary, effervescing draughts, or an opiate. Patients with heart disease, it is well known, are unfavourable subjects for operation under any circumstances; and if they become infected with an animal poison during or subsequent to the operation, have but little chance of recovery. A man, who had dilatation and thinning of the heart, took ether last year, in St. George's Hospital, whilst amputation of the leg was performed. He was attacked with sloughing phagedena, then prevalent,

and died on the seventh day, in one of the cold fits attending the disease, there being apparently not strength enough in the heart to establish a reaction from the rigor. And in the case of a gentleman who inhaled chloroform this last summer for the removal of a tumor, and became affected with erysipelas and diffuse cellular inflammation, the symptoms took on a peculiarly low type, and he died on the fifth day. After death there were found dilatation of the heart and thinning of its walls.

As narcotics are usually injurious when there is a tendency to congestion of the brain, it was apprehended by many practitioners that ether and chloroform would be unsafe for such patients; probably the transitory nature of the narcotism induced by inhalation, during an operation, is what renders it harmless. At all events, I have met with no ill results, although some of the patients had suffered from attacks of apoplexy, followed for a time by hemiplegia. This was the case in a man aged 66, on whom Mr. Keate operated, in St. George's Hospital, on the 3rd of August last, for the removal of a tumor situated on the thigh.

It is desirable to give some direction respecting the diet of patients about to inhale chloroform, for if it is inhaled immediately after a meal, there is increased liability to vomiting; and, on the other hand, it is not advisable to inhale after a long fast, for when sickness has occurred in this condition, it has been, in some instances, of considerable duration, and accompanied with more than usual depression. The best preparation appears to be a very moderate breakfast or luncheon two or three hours before the inhalation. The operations in the hospitals are usually performed soon after the patient's dinner hour. The most suitable arrangement in these establishments seems to be, that the subjects of operation should have no dinner, but should have a slender lunch during the forenoon; such as a little bread and butter, bread and milk, or gruel.

Chloroform in amputations.

When moving the patient from his bed to the operating table would cause great pain, as in some cases of ulceration of the cartilages of the knee-joint, the chloroform may be administered with advantage, so as to induce insensibility prior to his being moved. In University and King's College Hospitals, I have exhibited chloroform in several cases of this kind, in the wards, previous to the removal of the patient to the operating theatre, and have afterwards given some more of the vapour just before the operation. In St. George's Hospital this has not been required, as patients so situated have been carried to the theatre on their beds. I have sometimes given just enough chloroform or ether to children to produce unconsciousness, merely to prevent the fright they would experience from seeing any of the preparations for an operation.

The position of the patient usually chosen by the surgeon in the larger amputations—that on the back, with the head and shoulders raised—is very convenient for the chloroform. If the sitting posture is preferred for amputations of the upper extremity, it is desirable to have the patient's back well supported, and the legs raised and supported, either on the couch, or another chair; otherwise he will be liable to slide off his seat when insensible. The tourniquet may be put on either before the inhalation, or after insensibility is induced, but, if before, the screw should not be tightened till afterwards. The tourniquet is occasionally applied during the inhalation in the hospital, in order to save time, and then I inform the patient of the nature of what is being done, that he may not be in dread of the premature use of the knife. It is a good plan to let the patient inhale in a comfortable posture, and then to draw him to the edge of the table, when this is required, just before the operation is commenced.

If two fluid drachms of chloroform be put into the inhaler that has been described, they will usually more than suffice to last to the end of the operation. The face-piece should be at first applied with the expiratory valve turned aside, and this valve should be gradually moved over the aperture, more or less quickly, according to the patient's power of inhaling the vapour, without coughing or complaining of its pungency. So long as he is conscious, his feelings should be attended to, and

if nervous, he should be encouraged to persevere with the inhalation; but, when no longer conscious, his apparent dislike of the vapour must not prevent its continuance. The majority of patients become quietly insensible without offering any resistance; but, now and then, the patient, on entering the second degree of narcotism, feeling something unusual, and the purpose of it having escaped from his mind, tries to get rid of the apparatus, and it is necessary to hold his hands. Whilst any voluntary motion continues, either in the eyelids or any other part, all that is required is to go on giving the vapour steadily and gradually. It is seldom necessary to close the expiratory opening completely; it is usually sufficient if the valve cover three-fourths of it, and, if the patient breathe deeply, it should not be more than half covered. When voluntary motion is no longer apparent, in order to become informed respecting the state of the patient, the eyelid should be gently raised, touching its free border. If he look up, it is evident that the narcotism has not exceeded the second degree. If no voluntary motion be excited, the third degree is probably attained, and if the eye be found turned up, this is pretty certain. But, notwithstanding this, if involuntary winking be occasioned by touching the edge of the eyelid, it is necessary to continue the vapour a little longer before the operation is commenced. In doing so, however, if the narcotism have already reached the third degree, and there be no particular rigidity or struggling, the valve may be opened a little further, so as to give the vapour in a more diluted form, or the inhalation may be intermitted for two or three inspirations at a time. In this way, insensibility of the nerves is obtained, without increasing the narcotism of the nervous centres. As soon as the sensibility of the conjunctiva is abolished, or so far blunted that the free edge of the eyelid, or the eye itself, can be touched without causing decided winking, the operation may be commenced with confidence that there will be no pain, and no involuntary flinching that will interfere with the operation. When there is struggling, or great rigidity, in the third degree of narcotism, it is requisite to continue the vapour a little longer till it subside. If there be any approach to stertorous breathing, the inhalation should at once be suspended, as was stated in a former paper. Stertor, however, never begins till the patient is perfectly insensible. The time occupied in the inhalation is usually from two to three minutes. The operation having been commenced, the medical man having charge of the chloroform should watch the patient's countenance, and if there be any sign of returning sensibility, give a little more vapour during the short time occupied in removing the limb. After the amputation is completed, the vapour need not be repeated until there is decided evidence of sensation. When the arteries to be tied are not numerous, it is sometimes not necessary to repeat the inhalation. Generally, however, it is requisite to give a little chloroform at intervals, and if cold water have to be applied to stop the oozing of blood, or the flaps have to be united by sutures, it is advisable to keep the patient partially insensible till this is done.

Part IX.

1. *Condition of patients subsequent to amputation under chloroform.* 2. *They are not more liable to secondary hæmorrhage.* 3. *Statistics of result of amputations under ether and chloroform.* 4. *Their administration in minor amputations.* 5. *In lithotomy.* 6. *Results of cases of lithotomy.* 7. *Chloroform in lithotrity.* 8. *In the treatment of stricture.* 9. *In operation for necrosis.* 10. *In the removal of tumors of the female breast.* 11. *In the removal of tumors of the maxillary bones, and other large operations on the face.*

1. In amputations under chloroform, the patient is not only saved the immediate pain of the operation, but generally, also, the greater part of the subsequent smarting; for the common sensibility usually remains more or less blunted for some time after the return of consciousness, and the smarting is often not felt at all for half an hour after the operation, and then but slightly. In a few cases, however, pain is felt in the wound as soon as consciousness returns. In two or three cases in which the smarting was dis-

tressing, I have exhibited a little chloroform, from time to time, with complete relief, during the first hour or two that followed the operation; after which the pain shewed no tendency to return. I have tried the local application of chloroform, over the wound, in one or two instances, but it was applied external to other dressings, and not much effect was observed from it. The nervous system is tranquillized by the chloroform inhaled during amputations, and the spasmodic starting of the stump, that without its use would generally be distressing, hardly ever occurs.

2. One of the reports in circulation, soon after the inhalation of ether was introduced, was, that it gave rise to secondary hæmorrhage—probably some surgeon met with it in one or two cases. Secondary hæmorrhage, however, is by no means common after either chloroform or ether. Although I have administered one or other of these vapours in fifty-seven cases of the larger amputations, there has not been secondary hæmorrhage of any consequence, except in two instances, and it has been equally uncommon after other operations. As inhalation prevents the fainting that would otherwise often attend an operation, and generally also stimulates the circulation more or less, we might expect that it would facilitate the tying of all the vessels, and thus be a means of preventing secondary hæmorrhage; and experience seems to confirm this view.

3. Preventing the severe pain of the larger operations may reasonably be supposed to have some effect in diminishing their danger; and as the result of the larger amputations had previously been made the subject of statistical inquiry, they at once suggest themselves as a means of comparing the present with former practice. But a statistical inquiry is evidently incapable of shewing what is the direct effect of the use of chloroform and ether on the mortality resulting from operations. For, if a slight difference should be found, it might be supposed to depend on the altered circumstances under which operations are sometimes performed since the introduction of anæsthetics; as, on the one hand, patients are occasionally induced to submit to them earlier, and when the circumstances are more favourable than they otherwise would be; and, on the other hand, an amputation is now and then undertaken, when the patient is so reduced, or his prospect of recovery from it so bad, that it would not performed if the pain had to be inflicted. Still, it is proper to make a statistical inquiry, as it would be interesting to know whether the use of those agents has any appreciable effect, direct or indirect, on the mortality; and it may assist to dispel the fears of those, if any such remain, who think that the inhalation of them would be attended with notable ill consequences. With this view, I will here give the result of all the large amputations in which I have administered chloroform or ether. Although the number of cases I have to furnish is not large enough to determine this question, it will serve as a contribution towards that object.

The amputations in which ether was the substance employed, were 32 in number, and took place in 1847; those with chloroform were 25. Of these 57 amputations, five occurred in private practice; three of the thigh, of which two ended fatally; one of the leg, and one of the arm, both followed by recovery; 39 were performed in St. George's Hospital; 22 were amputations of the thigh, amongst which were six deaths; 13 of the leg, followed by three deaths; two of the arm, with one death; and two of the fore-arm, both ending in recovery. Eight of the amputations took place in University College Hospital; five of the thigh, all ending in recovery; two of the leg, in one of which the patient died; and one of the arm, which terminated fatally. Four amputations of the thigh occurred in King's College Hospital, with one death; and there was one amputation of the leg in the Hospital of the Fusilier Guards, performed by Mr. Judd: the patient recovered. The deaths were each occasioned by some well-recognised cause, which the inhalation could neither induce nor prevent: generally erysipelas or inflammation of the veins.

The following table shews the result of all these cases together. None of them remain under treatment; and all the patients who did not actually recover, are included in the deaths, by whatever cause decease was occasioned:

Seat of Amputation.	No. of Cases.	No. of Recoveries.	No. of Deaths.	Deaths per cent.
Thigh	34	25	9	26
Leg	17	13	4	23
Arm	4	2	2	—
Fore-arm	2	2	0	—
Total	57	42	15	26

If the two cases of amputation of the fore-arm be withdrawn, the total mortality will be 27 per cent. instead of 26. None of the above amputations were performed immediately after an accident, but were all either for disease or injuries sustained some time previously.* The mortality in the above cases is a little higher than shewn in a return by Dr. Lawrie of the amputations (primary ones being excluded) at the Glasgow hospital a few years ago,† but is much lower than a similar return by Prof. Malgaigne, from the Parisian hospitals.‡

In a collection of cases of amputation, from various hospitals, under ether and chloroform, in the Monthly Journal of Medical Science, April 1848, by Dr. Simpson, the mortality appeared much lower than in any previous tables; but as Dr. Simpson gave no instructions in his application for the return of amputations, that cases still under treatment should be excluded, there is reason to apprehend that he may have included such cases in his table, some of which may have since ended fatally. The return I furnished to him of operations under ether at St. George's Hospital is not correctly inserted in his table. Against the seven cases of amputation of the leg, there is a cypher in the column for deaths, where the number 1 ought to stand. This death arose from sloughing phagedena of the stump. I conclude that the discrepancy was occasioned by some mistake, and that, as I have mentioned it to Dr. Simpson, it will be corrected in his future tables; for I cannot suppose that it was intentionally withdrawn from the deaths, on account of the disease under which the patient succumbed.

4. In amputations at the ankle-joint, or tarsus, it is of course as needful to give chloroform as when the limb is divided higher up. Amputation of a finger or toe is an operation in which it is generally very desirable to inhale the vapour, as the pain of an amputation by no means diminishes in the same proportion as the size of the part on which it is performed. No particular directions are required respecting the mode of giving chloroform in the minor amputations, as what I have said concerning the larger ones is equally applicable to them.

5. Lithotomy is an operation in which I believe that every surgeon now considers it desirable, if not almost a duty, to have his patient made insensible. The practice of tying the hands and feet together with a bandage, to retain the patient in the required position, is still very properly resorted to. It is better to give the chloroform, so as to remove consciousness, before either the bandaging or introduction of the sound. This is especially desirable in the cases of children, and it is also the best plan in adults, as they begin the inhalation more at their ease. During the bandaging and sounding the effect of the vapour partially goes off, and therefore the inhalation must be resumed for a short time, so as to insure complete insensibility when the incision is made. The symptoms of insensibility were described in the last paper treating of the larger amputations. The patient should not be allowed to recover either consciousness or sensibility till the operation is completed by the extraction of the stone; and therefore, except when the operation is concluded in an unusually short time, it is necessary to give a little vapour from time to time, whenever the eyes shew that the patient is about to wake, or any slight shrinking or moaning indicates the beginning of

* There have been eight amputations in St. George's Hospital performed immediately after injuries, in which ether or chloroform has been administered by one of the resident medical officers. Five of the patients recovered, two died, and one remains under treatment, going on favourably.

† Med. Gaz. vol. xxvii. p. 394.

‡ Archiv. Gén. de Médicine, tom. lviii. p. 40.

uneasy sensations. It must not be supposed when there are obscure indications of sensation from time to time during an operation, that there is severe pain of which the patient is unconscious, for the truth is, that sensibility returns gradually, as we learn, by actual observation, in those cases where complete consciousness returns before the common sensibity. Under these circumstances, the patient, when first beginning to feel, describes as something pricking or pinching, measures that would without anæsthesia cause intense pain, and does not yet feel what at another time would be attended with considerable suffering.

6. The cases of lithotomy, in which I have administered ether or chloroform, are nineteen in number, of which fourteen ended in recovery, and five in death. Eight of the operations were performed in St. George's Hospital, the patients being all children. They all recovered but one, and in that case there was extensive disease of the bladder and kidneys, one of which was dilated so as to form a pouch. Five of the cases occurred in University College Hospital, under the late Mr. Liston; two of the patients were children, and recovered; three were adults, of whom two recovered, and one—a very old man—died. Two of the cases were in King's College Hospital, both in children, and ended in recovery. And there have been four cases in private practice, all those of adults, three of whom died a few days after the operation, and one recovered. The three patients who died were far advanced in life, and their disease was of long standing. The patient who recovered could not have got through the operation had it not been for the chloroform: such was the opinion of Sir B. Brodie and Mr. Coulson. I alluded to this case in a paper I read last winter.*

It will be observed that twelve of the above cases were those of children, and that all of them recovered but one, who had a mortal disease at the time of operation; and that of the seven adults, four died. This difference between the mortality of lithotomy in childhood, and in the later periods of life, is in accordance with the usual experience of surgeons. I may remark of the cases that were fatal, that death was the result of causes quite independent of the narcotic vapour, as in all the other cases that I have seen in which operations have ended unfavourably.

7. Chloroform is generally given in St. George's Hospital in lithotrity. As the pain of this operation is usually not excessive, inhalation would not be employed if the surgeons did not feel quite satisfied of its perfect safety, and freedom from all ill effects. I have always seen the operation very satisfactorily performed under chloroform, both in this hospital, and on two occasions when I assisted Mr. Henry Chas. Johnson with it, in private practice. Besides preventing what pain there would be, the surgeons find that the chloroform has the further advantages of preventing the straining efforts of the patient, and enabling them to seize and crush more fragments at one operation than they otherwise could.

The chief suffering from lithotrity is often in passing the fragments; and in dismissing this subject I may allude to the opinion of the late Mr. Liston, expressed to his class in 1847, that the discovery of etherization would be a reason for choosing lithotomy in some cases, where otherwise crushing the calculus would be preferred, as the former operation at once frees the bladder from irritation, and is now stript of its greatest terror.

8. In the division of the urethra in the perineum, chloroform or ether is of course as necessary as in lithotomy. I have assisted with the inhalation in several such operations. One case may be alluded to here, on account of its important bearing on the treatment of stricture. It was a case in which this operation was about to be performed by Mr. Liston in University College Hospital, but was not required, owing to the relaxing effects of ether on the stricture.

John Willis, aged 42, had stricture of the urethra, caused by an injury twelve years before. He had passed his urine in a very small stream for the last three years, and latterly only by drops, and no catheter could be introduced, although it had been frequently attempted. When the patient was got fully under the influence of ether, a Number 1 catheter was introduced with the intention of passing it down to the stricture, preparatory to dividing it, by an incision in the middle line of

* Lancet, Feb. 12, 1848.

the perineum; but it passed right on into the bladder, and the intended operation was not required. This took place on June 18, 1847; the catheter was retained in the bladder till the 23rd, when No. 2 was substituted for it, and subsequently larger catheters, and the patient went out cured on July 27th, being able to pass his urine in a good stream.

9. There are no operations in which the utility of narcotic vapours is greater than in those for necrosis—operations that are generally of considerable duration, and which are amongst the most painful in surgery, on account of the great sensibility of the inflamed bone surrounding the sequestrum. I have given ether and chloroform in nearly thirty operations for necrosis in St. George's Hospital, besides a number elsewhere. The action of the vapour has always been quite effectual in preventing the pain. The majority of the patients were children, and during a great part of the time occupied in the operation narcotism generally did not exceed the second degree; that is to say, there was a dreaming or wandering condition of the mind, and not a state resembling coma.

10. The extirpation of tumors is perhaps the most frequent operation in surgery; but tumors differ so much in size, situation, and every other respect, that there would be no advantage in stating the general result of their removal. Operations for the excision of tumors of the female breast, however, sufficiently resemble each other to admit of such a statement being given.

The number of cases in which I have had to give ether or chloroform, for the removal of tumors of the female breast, involving the gland, is thirty-four. Nineteen of them were in private practice, in seventeen of which the patients recovered from the operation, and in two cases the patients died—one of them of pleurisy, and the other, apparently, of exhaustion. The other fifteen patients were in St. George's Hospital: thirteen recovered from the operation, and two died—one of peritonitis twenty-four days after the operation, the other of erysipelas.

By far the greater number of these tumors of the breast were of a malignant nature. There has not yet been time to ascertain the ultimate effect of the operation on the disease; and, indeed, I am not able to give the result to the present period. The patients in the hospital leave when they have recovered from the operation, and generally are not heard of again; and I only hear now and then, through their surgeons, of some of those in private practice. I am able, however, to state that some of the patients are now in pretty good health, who must long since have died a lingering and painful death if no operation had been performed. Any objections that existed to the removal of malignant tumors must have been greatly diminished by the introduction of narcotic vapours. Each case must, of course, be judged on its own merits; but the number of cases in which an operation may be properly recommended, and in which it will be submitted to, when the whole question is laid before the patient, must be considerably increased by the discovery of the means of rendering it devoid of pain.

11. The only surgical operations that present any difficulty to the total prevention of pain during their performance, are operations of considerable magnitude and duration, which involve the cavity of the mouth or nose, such as the removal of tumors of the maxillary bones. The patient can be rendered insensible before the operation, in the usual way, as easily as in other cases; but the difficulty is in repeating the inhalation so as to preserve the immunity from pain till its conclusion. It is best, in operations of the face, to exhibit the vapour well diluted, so that insensibility may be induced gradually, by which means the fluids of the body get more thoroughly impregnated, and its effects are more permanent. When inhalation of chloroform extends over three or four minutes, and the third degree of narcotism is well established, with insensibility of the conjunctiva, it is generally about three minutes before there are distinct signs of pain from the use of the knife. The effects of ether are, I think, a little more lasting, and therefore it would be preferable in such operations, were it not that chloroform can be more easily reapplied during the operation. To effect this, I drop a few minims of it, from time to time, on a sponge that has been squeezed out of cold water, and as soon as the patient evinces any sign of pain,

I apply it near to his mouth and nostrils for a moment, whenever the position of the surgeon's hands, and those of his assistants, will permit. In this way, if the pain cannot all be prevented, the patient can generally be kept so unconscious that he afterwards says that he felt nothing. It is only in protracted operations that the use of the sponge in this way is required, for the greater number of operations are concluded in two or three minutes.

There are some surgeons who think that chloroform in operations involving the mouth, and attended with considerable hæmorrhage, is not altogether free from the danger of blood getting into the trachea. This point requires to be very carefully considered, for whilst it would be improper to run a risk of this occurrence, the pain of large operations on the face is so frightful that the inhalation ought not to be interdicted on mistaken grounds. There are good physiological reasons for believing that the sensibility of the glottis would last, under the influence of narcotics, as long as respiration continued to be performed; but the best evidence will be that derived from experience. I have seen a great number of operations attended with considerable hæmorrhage into the mouth, in which ether or chloroform has been given, and no ill effects have followed in any case. The result of my observation consequently is, that there is no danger of blood getting into the air passages when these agents are carefully given, and the same attention is paid to the patient's position and breathing that would be in the absence of insensibility. There was one operation at which I assisted last summer, where the patient died soon after it was performed, and as I have heard that a report got abroad, in some parts of the medical world, that death was occasioned by blood entering the air-passages, it may here be mentioned:—

The patient was a young man, with a large fibrous tumor in the situation of the left superior maxillary bone. For some time previous to the operaton he had suffered occasionally from hæmorrhage from the affected nostril, to an extent which had reduced him considerably. The vapour was given to him rather slowly, with the apparatus I commonly employ, and he became gradually insensible, without previous excitement or struggling. In about three minutes the inhalation was discontinued, the narcotism having reached the third degree. The patient was passive, but the muscles were not relaxed. The breathing was not stertorous. Some teeth were now extracted without causing any sign of pain. A little more chloroform was then given to him, and when the inhalation was discontinued a second time he was in the same state as before the teeth were drawn. The operation was immediately commenced. I took no notes of the method in which it was performed, but can state that the superior maxillary and malar bones of the left side were removed. During the first part of the operation, whilst the flaps were made, the patient was perfectly quiet and silent; but afterwards he began to groan and move his limbs, and he was not again rendered altogether insensible; for although a few minims of chloroform were from time to time sprinkled over a sponge, which was, now and then, held near his face, yet, owing to the hands of the operator and his assistants being in the way, and the cavity of the mouth and nostril being laid widely open, he got very little of the vapour, and the only effect of it was partially to quiet him on one or two occasions. After the first two or three minutes of the operation the effect of the chloroform never exceeded the second degree. The patient executed voluntary movements of his arms and legs; sometimes it was necessary to hold his hands, and at one time he appeared conscious, for he folded his arms as if making an effort not to raise his hands to the seat of pain. He coughed now and then, and seemed somewhat embarrassed with the blood in his throat. He was seated in a chair, but as there was no window in the operating theatre except the skylight, his head was obliged to be inclined rather backwards. He was leaned forwards once or twice, to allow him to get rid of the blood, and it appeared that he vomited some on one of these occasions. Towards the conclusion of the operation, and at a time when he was very little under the influence of chloroform, he fainted. He was laid down, and brandy was given to him. No more chloroform was administered after this time. He partially rallied from the syncope, but again

became faint. The actual eautery was applied, but oozing of blood eontinued until the moment of death,—about half an hour after his removal into another room. During this interval he was mueh exhausted; his pulse was small, and difficult to feel. He was tossing himself about in a restless manner, but there was no diffieulty of breathing. He seemed quite eonseious, doing as he was told, but, of eourse, eould not speak, from the nature of the operation. I left a few minutes before the patient's death. When he eeased to breathe, traeheotomy was performed, and artificial respiration exereised by the opening, with no benefieial result. In my opinion this measure was not indieated, but of eourse it could do no harm.

After death, portions of the tumor were found still remaining attaehed to the posterior and upper part of the cavity, and projeeting into the foramen lacerum of the orbit and right nostril, as well as in other direetions. The traehea and bronehi eontained some frothy blood. Numerous small dark spots of congestion were met with in the lung, resulting from some of the small bronehi being filled with blood.

It is evident that the ehloroform did not eontribute, either direetly or indirectly, to this patient's death, for the following reasons:—1st. That the tracheotomy and artifieial respiration suffieiently aeeount for the small quantity of blood found in the bronehial tubes. (An eminent physieian-accoucheur has informed me that in cases of still-born ehildren, in whieh he has performed artifieial respiration by an ineision in the larynx, he has always found blood, after death, in the bronchi.) 2nd. If there had not been this reason for blood in the lungs, it would be more likely to have entered when the patient was moribund, or during the syneope, than at an earlier period. 3rd. That the symptoms did not indicate any impediment to respiration, but were such as I have seen in uterine hæmorrhage, and sueh as were met with after the removal of the superior maxillary bone by a very eminent operator in this metropolis, before the introduetion of ether. 4th. That if the judieious use of ehloroform caused a liability to the entranee of blood into the bronehi, there would have been some symptoms of it in the numerous patients who have reeovered from similar operations in the narcotised state; but sueh is not the case. And 5th. That the quantity of blood met with in the lungs was not enough to cause rapid death.

In dismissing this case, I wish to state my belief that the operation was a very proper endeavour to cure the patient of a disease that must inevitably have been fatal in a short time; and that my reason for alluding to it is, that if I should leave it unnoticed, in treating of ehloroform in operations on the faee, I might be suspected of keeping baek a material faet.

I will now enumerate the other operations, for the removal of larger tumors of the jaw, in which I have exhibited nareotie vapours.

In May 1847, Mr. Liston removed a large tumor of the lower jaw, in a young lady, dividing the bone far baek, near the rami, on each side. He was assisted by Mr. Morton, Mr. Cadge, and others. The patient took ether.

On December 23, 1847, Mr. Henry Charles Johnson removed one of the superior maxillary bones of a young man, in St. George's Hospital, for a large tumor. This, and the remaining patients, inhaled ehloroform.

A few days after the last operation, Mr. Fergusson removed a large tumor of the lower jaw, oeeurring in a gentleman. Sir B. Brodie was present.

Early in January 1848, Mr. Fergusson also removed a large tumor of the upper jaw of a middle-aged woman, in King's College Hospital. The tumor had been removed onee before, but had returned.

In May last, Mr. Tatum removed a very large tumor of the lower jaw of a Spanish gentleman, in St. George's Hospital, dividing the bone near its symphisis, and disartieulating it on one side.

In November last, Mr. Fergusson removed a tumor of the superior maxillary bone in a little girl, in King's College Hospital.

In the same month, Mr. Fergusson also removed a tumor of the lower jaw in a young man, a patient in the same hospital.

The above patients all recovered favourably from the operation.

I have seen chloroform and ether employed, also, in a number of other operations in whieh a good deal of blood flows into the mouth and throat; sueh as operations for epulis, and

polypi of the nose. Sometimes the patients can be observed to swallow the blood, with an act of deglutition; but usually it seems to flow down the pharynx and œsophagus without distinct muscular effort; and if the quantity of it is not very large, it does not in any way interfere with the glottis.

When infants are laid on the back, during the operation for hare-lip, the blood is swallowed, whether they are narcotised or not; and when they are insensible, it goes down with less appearance of choking than when they are crying from pain.

Part X.

1. *Ether and Chloroform in operations on the teeth;* 2 *on the eye;* 3. *on the anus;* 4. *on the back.* 5. *Inhalation to facilitate the reduction of hernia;* 6. *of dislocations;* 7. *to aid diagnosis;* 8. *to save the moral feelings of the patient.* 9. *Occasional sequelæ of inhalation—sickness;* 10. *its treatment.* 11. *Headache.* 12. *Hysteria.*

1. Chloroform is, I believe, not very generally employed in tooth-drawing in this metropolis. This is partly owing to the circumstance, that the pain occasioned by the operation, though severe, is usually but momentary; but another reason appears to be, that the majority of dentists are not sufficiently acquainted with the application of the medicine to be satisfied that they can use it with perfect safety, and it is not always convenient to the patient to have another medical man present. It is only in the cases of children and very nervous persons, who have not resolution to keep the mouth voluntarily open for the operation, that narcotism facilitates the work of the dentist; in other cases it adds to his trouble, and occupies more of his time. The introduction of ether and chloroform has been of service to the dental profession, having increased the practice of many of its members, by relieving the springs of industry from the incubus of the dread of pain; for a number of the operations under these vapours would not have been performed except for their use. I allude to many of the cases in which the mouth is "cleared," as the term is, of a number of decayed teeth, and stumps of teeth, to make room for a set of artificial ones—a process which is now generally performed at one or two sittings, without any pain, and which cannot fail to be, ultimately, of great benefit to the patients.

It is desirable not to carry the narcotism further than the third degree for the extraction of teeth, and in this stage there is generally some rigidity of the muscles of the jaw, but this can nearly always be overcome by pressing the chin down. It has been recommended that a wedge should be placed in the mouth before the inhalation, but I have never seen it necessary to have recourse to this plan, as I have always been able, with the assistance of the operator, to get the patient's mouth open. The few instances in which the mouth could not be at once opened were cases in which voluntary power was exerted under a dreaming condition of the mind, and in these cases the exhibition of a little more of the vapour enabled the desired object to be effected. There was one instance in which the addition to the dose of vapour was prevented by hysterical symptoms, till the lady recovered her consciousness, and then she had sufficient courage, and preferred to have her tooth removed without the repetition of the inhalation, which there is no doubt would have been effectual, as in every other case that I have seen. As it was, the pain was probably diminished. It has always appeared to me that there was a diminution of muscular power under the effects of chloroform and ether, in every variety of their operation; the voluntary efforts under excitement are much less powerful than those of an exasperated individual in an unnarcotised state, and the involuntary rigidity in the third degree is still more easily overcome. As there is usually less rigidity from the use of ether than chloroform, the former would be preferable in tooth-drawing, were it not for the strong odour that it leaves in the breath for the rest of the day. When teeth require to be removed from both jaws, those in the lower one, especially if they be molars, should be first extracted; otherwise, as the patient is unable to wash out his mouth, the blood will render them obscure. To clear the mouth of blood, whilst ope-

rating on the teeth of the lower jaw, it is sometimes desirable to use a sponge squeezed out of warm water. If the sensibility is found to be returning before all the teeth are extracted, the inhalation must be resumed for a short time before proceeding further. There is sickness after the use of chloroform in some instances of dental as of other operations, and it is here felt to be more annoying than after a great operation where the patient is necessarily an invalid. I shall have to speak of the treatment of sickness further on.

I am not an advocate for the use of chloroform in every instance of tooth-drawing, but I do not see how any rules can be laid down respecting its employment, as a good deal must depend on the wishes of the patient as well as on the presumed severity of the operation. One point, however, should be imperative, viz. that chloroform should not be given except by medical men who have made themselves well acquainted with its effects and mode of application. I have a strong feeling that severe pain ought not to be inflicted on children, since the means of preventing it have been discovered, and act so favourably on them; and therefore, when a tooth is to be removed that is firmly fixed, I think that a child should be made insensible whenever there is the knowledge requisite to effect this with perfect safety.

2. In most operations on the eye, narcotism is of essential service. In the operation for strabismus, the amount of pain to be prevented is considerable; and as the patients are usually children, who would offer all the resistance in their power, the proceedings of the surgeon are very much facilitated, as Prof. Miller, of Edinburgh, has recently remarked.* Chloroform or ether may be given with advantage to children, in operations on the eye unattended with pain, merely for the purpose of keeping the patient and the eye motionless. I have given the vapour of one or other of these medicines several times for Mr. Cæsar Hawkins and Mr. George Pollock, whilst operating on congenital cataract by the method of drilling. Two or or three of the latter gentleman's patients were only a few weeks old. The operation was facilitated in all the cases. In the excision of cataract, it is not advisable to administer ether or chloroform, for if vomiting should be induced it would be likely to cause serious mischief; and although vomiting is not a frequent result of inhalation, when precautions are taken to prevent it, yet it is impossible, I believe, to predict with certainty in any case that it will not occur.

3. Operations on the anus are frequently required, and they are of a very painful nature, on account of the great sensibility of the part. It was the practice of most surgeons before the introduction of inhalation, to have the patient standing on the floor, in a stooping posture, and leaning over a table or bed; but this attitude could scarcely be maintained in a state of insensibility, and therefore the practice now is to let the patient lie on his side, with the knees drawn up towards the abdomen; or when that is more convenient to the surgeon, the patient can lie on his back, as for lithotomy. The chief operations on the anus are that for fistula, the excision of hæmorrhoids, and the cutting away of loose folds of integument from the verge of the anus, for the cure of prolapsus. It is necessary to have the patient completely insensible in operations on this part, more especially in that for fistula, as any involuntary flinching during its performance would be a serious inconvenience.

4. For the removal of tumors from the back, and the performance of any other operations in that situation, it is best to let the patient inhale whilst lying on his side, and when he is insensible to turn him over, in a great measure, on his abdomen, allowing his head to remain in its former position on the pillow: in this way the inhalation can be repeated, if required, during the operation.

It is unnecessary to enumerate other operations, as they do not require any special directions, as regards the chloroform or ether. There are some cases to be mentioned, however, in which narcotism is attended with signal benefits, in addition to the prevention of pain.

5. There have been several cases of strangulated hernia, in which the inhalation of ether or chloroform has

* Surgical Experience of Chloroform.

enabled the bowel to be replaced by the taxis, after previous efforts had failed, and where an operation must otherwise have been performed. I am not aware how soon etherization was employed with this happy result, but the earliest case that I find recorded is that of a patient of Mr. White in the General Hospital, near Nottingham: it occurred on March 22nd, 1847, and the ether was administered by Dr. Sibson.* On July 10, 1847, there was a similar case under the care of Mr. Stafford, in the Marylebone Infirmary.† On March 6th, 1848, a man, James S., was placed upon the operating table, in St. George's Hospital, with a strangulated inguinal hernia: I administered chloroform to him at the request of Mr. H. C. Johnson, who had the treatment of the case; and when the patient became completely insensible, and the muscular system relaxed, the hernia was readily reduced by means of the taxis, although it was previously quite incapable of reduction. If the taxis had not been successful, the operation, for which the instruments were arranged ready, would at once have been performed, whilst the patient was still insensible. In the case of another patient, a woman with femoral hernia, who was placed on the table immediately afterwards, Mr. Johnson performed the operation as soon as she was rendered insensible, without employing the taxis, being deterred by the tense and inflamed condition of the tumor. This case ended favourably, as well as the former one. There are several other cases recorded in the medical journals of this and other countries, besides the three above enumerated, in which the use of ether or chloroform has enabled the surgeon to reduce a strangulated hernia without the operation.

6. Narcotism by inhalation facilitates the reduction of dislocations of the bones, besides preventing the pain of the process; and it has enabled the surgeon to reduce dislocations of long standing, which could not otherwise have been relieved. On June 24, 1847, Mr. Tatum reduced a dislocation of the shoulder of ten weeks' standing, with the aid of the pullies, in St. George's Hospital, whilst the patient, Richard R., aged 31, was under the influence of ether. The dislocation, which happened in the country, had been first overlooked, and when detected, could not be reduced. On February 7th, 1848, a dislocation of the femur into the ischiatic notch, which had existed for about three weeks, was reduced with the aid of the pullies, in the same hospital, by Mr. H. C. Johnson; the patient, Patrick C., an Irish labourer, being made insensible, and his muscles being relaxed, with chloroform. Three days afterwards, Mr. Tatum reduced a dislocation of the hip, in the hospital, of five weeks' standing; the patient, Joseph G., a working man, being put under the influence of chloroform. I have also given the vapour, in St. George's Hospital, in some cases of old dislocation, in which the position of the parts has been improved by the efforts made during the state of insensibility and relaxation, although their condition did not admit of complete reduction: two cases of dislocation at the elbow-joint were of this nature. Some cases of recent dislocation have been reduced under the influence of narcotic vapours, when previous attempts at reduction had been unsuccessful. Two cases of dislocation of the thigh-bone, in which Dr. Sibson administered ether, at Nottingham, were of this nature. One into the ischiatic notch, reduced by Mr. White, April 7th, 1847; the other on the dorsum ilii, reduced by Mr. Caunt, May 31st, 1847.* I assisted Mr. H. C. Johnson by giving chloroform to a gentleman with a recent compound dislocation of the last phalanx of the thumb backwards. The previous efforts at its reduction had failed, on account of the pain occasioned by them being more than the patient could bear. When he was rendered insensible, the dislocation was soon reduced.

Chloroform was given in many of the above cases because it was in use at the time, and could be employed without the delay that getting the ether ready would have occasioned. It answered very well; but it is my opinion that ether is preferable, both in dislocations and strangulated herniæ, as it induces relaxation of the muscles more easily, and with less previous rigidity.

7. The artificial production of insensibility is frequently of the utmost service in assisting the surgeon to form

* See Med. Gaz. Vol. xl. p. 1009.
† Med. Gaz. Vol. xl. p. 115.

* See Med. Gaz. Vol. xl. p. 1009.

a diagnosis. I gave ether for this purpose at the request of the surgeons to St. George's Hospital, in February, 1847, to a little girl with disease of the knee and abscesses in the thigh. In this case, the great tenderness of the parts, and the nervous agitation of the patient, precluded every attempt to examine the state of the limb in the usual manner; but when the patient was rendered insensible, the condition of the limb was ascertained sufficiently to enable the surgeon to determine on amputation, which was performed on February 25th, by Mr. Henry James Johnson, the patient being again placed under the influence of ether. In several other cases of diseased joint and diseased bone, ether and chloroform have been employed in this hospital, to aid diagnosis in a similar manner. In sounding for stone, especially in children, it is of service to render the patient unconscious. I administered ether for this purpose in St. George's Hospital, as early as February 3rd, 1847, whilst Mr. Cutler sounded a little boy, aged four years. Dr. Thomas Smith, of Cheltenham, applied ether about this time, viz. on February 22nd, to enable him to ascertain the state of the corneæ of a child labouring under strumous ophthalmia.*

8. There are many operations on the female which medical students could seldom witness except at the expense of some shock to the feelings of the patient. They are now generally conducted in the hospitals in this wise:—The patient inhales and becomes insensible whilst only one or two surgeons and the nurse are present in the private ward, or behind the screen with her: the students then come in and witness the operation, and go away again before the consciousness of the patient has returned. In some operations in private practice, where the surgeon requires two or three assistants, they are not brought into the room till the patient is insensible, or she is made insensible in an adjoining room, and carried to the place selected for the operation.

9. Narcotism by chloroform or ether, to the extent required in surgical operations, occasionally leaves some effects after the immediate influence of the vapour has subsided: these may be called sequelæ. I have not observed that they are more frequent after one of these agents than the other. The only after-effects of inhalation with which I am acquainted are sickness, headache, and hysterical symptoms in those predisposed to hysteria.

Vomiting is apt to occur during the narcotism, or just afterwards. It can be rendered less frequent by the precaution previously mentioned,* of not allowing the patient to inhale soon after a meal, and also not carrying the narcotism further, if possible, than the third degree,—thus avoiding stertor and complete relaxation of the muscular system; but I believe that it cannot always be prevented by all the care that can be used, more especially if the inhalation have to be repeated, in order to keep up the insensibility for more than a few minutes. The vomiting no doubt depends on the action of the narcotic vapour on the brain, and is allied to that occasionally caused by opium and alcohol, and to that which occurs in some morbid conditions of the cerebrum. If the patient recover completely from the immediate effects of the vapour, without any feeling of sickness, he is not liable to it afterwards from that cause; and, in the greater number of cases in which vomiting does occur, the sickness goes off in a few minutes, and does not return; but in a few instances it continues for several hours, if nothing be done to relieve it, and in two or three cases it has lasted, under these circumstances, for two or three days. I have met with more or less vomiting in about one-fifth of the patients operated on, under chloroform, during the last six months: many of them, however, had received no previous directions respecting their diet. The number of cases in which there has been troublesome sickness has been one in twenty-six operations during the same period. I have never found the sickness continue more than five or six hours when I have been taking measures to relieve it.

Diminished temperature of the surface generally accompanies the sickness: indeed, the depression of the respiration and circulation attending it has a tendency at all times to lessen the development of animal heat. But

* See Med. Gaz. Vol. xl. p. 676.

* Last vol. p. 1024.

chloroform and ether, I am quite satisfied, have also the effect of diminishing the production of caloric, quite independently of their action on the respiration and circulation; and, when inhalation has been kept up for some time, I have remarked the patient to become rather cold in cases where no sickness was present.

10. When sickness has continued after the immediate effects of the vapour have subsided, and the stomach has been quite emptied by vomiting, I have generally found that a little wine or weak brandy and water has removed the sickness. When the patient is cold as well as sick, warm wine and water, or brandy and water, are preferable; and other measures to restore warmth should be resorted to, such as warm covering, drawing the sofa near the fire, if it be winter, or applying a feet-warmer, if the patient be in bed. In two or three cases these measures did not afford relief, and ten or twelve minims of Battley's solution of opium were given, with the effect of completely and permanently removing the sickness: these, of course, were adult patients, and I have not found sickness continue very long in children. The horizontal posture should, if possible, be preserved till the sickness has subsided, and for some time afterwards. It is desirable, indeed, to let the patient remain, without being moved or spoken to, till the narcotism has completely passed off, in every instance where it is practicable. The necessary removal of hospital patients from the operating theatre immediately after the operation causes sickness in many cases where I believe that it would not otherwise come on. I have not perceived any appreciable benefit from effervescing draughts, and I have not had occasion to try hydrocyanic acid or creosote. The application of ammonia to the nostrils sometimes seems to refresh the patient, but internally I think it is not so beneficial as wine.

The wine and opium recommended above are not given to combat the direct effects of chloroform, and should not be administered till the immediate influence of the vapour has subsided, unless it be the former, when it is required to remove faintness from loss of blood, which, however, seldom happens during narcotism. The opium probably acts by removing irritability of the stomach, occasioned by the vomiting, which was induced in the first instance by the state of the brain.

11. Headache is not a common result of inhalation: the few instances in which I have heard it complained of, occurred in persons in good health and inclined to plethora, and passed off spontaneously.

12. In describing the circumstances that modify the action of narcotic vapours, it was stated* that, in the hysterical diathesis, inhalation was liable to induce a paroxysm of the disorder, which might recur as the narcotism was diminishing. This usually soon subsides, but there are a few cases in which it remains troublesome for two or three hours. I have seen hysteria two or three times in the male, after ether and chloroform, in patients who had previously had the complaint. I have not found it to require any treatment, except in the case mentioned before;† and if it do, it should be treated in the usual way.

My own experience of hysteria, as a sequela of inhalation, is, that it forms no great impediment to its employment. Mr. Tomes,‡ however, has related three cases with which he had been made acquainted, where the disorder was more lasting and troublesome; and one case in which the use of chloroform was followed by worse effects than hysteria, viz. delirium, and subsequently an occasional vacancy in the patient's manner, leading her medical man to forbode insanity, sooner or later. In this last case, however, the patient had an overdose of the vapour, having been "almost pulseless — scarcely breathing," with a ghastly countenance. The chloroform was given by a dentist who evidently did not understand its effects, having first asserted that the lady was "under its full influence," when she, in fact, heard what he said, and then having given an overdose. The case only confirms a maxim, now beginning to be better understood than when chloroform was first suddenly brought into universal notice—viz. that it ought not to be used except by medical men who have studied its effects.

* Last vol. p. 1022.
† Loc. cit.
‡ See Review in Med. Gaz., last vol. p. 545.

Part XI.

The combination of chloroform and ether—of chloroform and alcohol—Chloric ether—Strong chloric ether—New mode of inhaling vapours.

It has been shown in former parts of this essay, that the action of chloroform can be rendered perfectly mild and safe by diluting it sufficiently with air. If the properties of this body were such, or if another body could be met with having such properties that the relation between its intrinsic power and its volatility would prevent the air from taking up so much vapour, under the usual circumstance of temperature and pressure, as could enable a patient to get an overdose without ample warning, this would be an advantage; as there would then be no fear of accidents in the hands of medical men, even when not armed with a suitable inhaler, and special experience on the subject. This, however, is not the nature of chloroform, and although there are substances of this character, of which I intend to give a further account, they do not possess, at the same time, all the other convenient and agreeable qualities which would enable them to supersede chloroform in the majority of surgical operations. As the most desirable strength of a volatile narcotic liquid, not requiring great care in its use, is between that of chloroform and that of sulphuric ether, it might be supposed that by mixing the two medicines the desired end would be attained: but such is not the case; they have been so mixed by some practitioners, and I have tried them together, but the result is a combination of the undesirable qualities of both, without any compensating advantage. Ether is about six times as volatile as chloroform—that is to say, if equal measures of each be placed in two evaporating dishes kept side by side, at the same temperature, the ether evaporates in about one-sixth the time of the chloroform; and when the two liquids are mixed, although they then evaporate together, the ether is converted into vapour much more rapidly; and, in whatever proportions they are combined, before the whole is evaporated the last portion of the liquid is nearly all chloroform: the consequence is that at the commencement of the inhalation the vapour inspired is chiefly ether, and towards the end nearly all chloroform: the patient experiencing the stronger pungency of ether when it is most objectionable, and inhaling the more powerful vapour at the conclusion, when there is the most need to proceed cautiously.

Chloroform was first employed for inhalation in the form of solution in alcohol, in which state it was called chloric ether. Mr. Jacob Bell was, I believe, the first person who exhibited it,* and it was afterwards employed occasionally in St. Bartholomew's Hospital, and in the private practice of Mr. Lawrence. This so-called chloric ether contained from twelve to eighteen per cent. of chloroform. When inhaled it yielded a little vapour of chloroform at the beginning of the process. Each hundred cubic inches of air passing over it, would take up, if saturated at 60°, from one and a half to two cubic inches, mixed with some vapour of spirit, and this was enough to produce insensibility if continued of the same strength, but by the time a third part of the liquid was inhaled, the quantity of vapour given off was reduced to less than half a cubic inch, which is insufficient either to induce or keep up insensibility; and when about half the chloric ether had evaporated, the remainder was reduced to spirit and water, with scarcely a trace of chloroform. Consequently, unless the inhaler were frequently emptied and replenished with fresh ether, insensibility failed to be induced; and under any circumstances the use of this preparation was troublesome and expensive.

In some able and interesting articles recently published in the Medical Gazette, Dr. John C. Warren, of Boston, U.S., has recommended a strong chloric ether, containing one part chloroform to two parts alcohol; this would be undoubtedly much more efficient than the ordinary chloric ether; but there is the same kind of irregularity in its effects, as in the case of the weaker preparation. The chloroform evaporates chiefly with the first portion of spirit, and when a little more than half the liquid has been used, the remainder contains very little chloroform, and is, therefore, of no use for inhala-

* See Pharm. Journ. Feb. 1847, p. 357.

tion, since vapour of alcohol has very little effect.

I had often considered the subject of diluting chloroform with spirit, and since Dr. Warren's papers appeared have given the matter additional attention. I have mixed chloroform in various proportions with alcohol of 92·5 per cent. and ascertained the quantity of vapour the compounds would give off. I have also placed these compounds in a current of air, in imitation of what takes place during inhalation, and by measuring the liquid from time to time, and weighing it in the specific gravity bottle, have been able to calculate the changes of composition which take place as evaporation proceeds. In so doing, a correction was made for the small quantity of water in the spirit, the proportion of which increases as the alcohol evaporates. The following table, which is as accurate as can be made without introducing fractions, shows how the proportion of chloroform decreases when it is mixed with an equal volume of alcohol, or with any other quantity marked in the table. For instance, when the hundred parts are diminished to sixty, they constitute the strong chloric ether of Dr. Warren, and the alterations in that compound are subsequently shown. The fourth column exhibits the quantity of chloroform in the mixed vapour that 100 cubic inches of air would take up, if saturated at 60°. The quantity that 100 cubic inches of air will thus take up from pure chloroform, is fourteen cubic inches.

Chloroform and Alcohol.	Alcohol.	Chloroform.	Cubic Inches of Vapour.
100	50	50	8·1
90	48	42	7·8
80	46	34	7·4
70	43	27	6·8
60	40	20	5·9
50	37	13	4·5
40	33	7	2·1
30	27	3	0·9
20	19½	½	0·0
10	10	0	0·0

Dr. Warren recommends the strong chloric ether, in order to prevent the accidents that have resulted from the too rapid action of chloroform. The quantity of vapour of chloroform that air would take up from this compound would, under the usual circumstances of inhalation, not exceed six per cent. —a proportion which, I believe, would not cause any sudden accident; but unless the person using it have such skill as would enable him to avoid the risk of accident in using chloroform, he would be liable to fail in producing insensibility with its solution in spirit, owing to its rapidly decreasing strength, and the diminishing quantity of vapour that it gives off: indeed, Dr. Warren has himself experienced the irregularity of the action of strong chloric ether, having failed to induce insensibility with it in two or three cases; but he attributes the failure to a defect of susceptibility in the patients, and he advises the resort to chloroform in such cases. This is virtually yielding the point, and incurring in some cases the very risk which the proposed practice is intended to obviate. A case which occurred recently in Westminster, the account of which had not reached America when Dr. Warren's papers were written, shows that an apparent want of susceptibility does not protect the patient from accident. In that case,* a gentleman, who, as I am informed, had many times used chloroform in the same way before, employed half an ounce on a handkerchief without making the man insensible; but, a fresh supply being obtained an hour or two afterwards, the patient got an over-dose, and lost his life, although the quantity used was not greater than on the previous occasion. When chloroform is given in such a way that the strength of the vapour can be regulated, it is found that there is no appreciable difference in the susceptibility to its action, whatever variety there may be in the symptoms induced previous to insensibility, and in the extent to which it is requisite to carry the narcotism in order to obtain relaxation or immunity from pain; and since it has been shown in the first three parts of these papers, that there is a definite rule for the proportion of chloroform and other narcotic vapours in the blood, which applies alike to animals of different classes, it cannot be supposed that any human being could form an excep-

* See Lancet, Feb. 24.

tion, since he would have to differ, not only from his own species, but from the animal kingdom in general.

When it is necessary to give chloroform on a sponge, during a surgical operation, it is not a bad plan to use it diluted with spirit, as recommended by Dr. Warren. In two or three recent cases of operation on the face, insensibility having been induced before the operation, by means of the apparatus as usual, it was requisite to employ the sponge to keep the patient insensible during its performance; and I employed a solution of chloroform in spirit, sometimes in equal parts, at other times in the proportion constituting the strong chloric ether. Both preparations answer the purpose very well, and can be employed more freely than undiluted chloroform. I poured, for instance, half a drachm or a drachm on the sponge at once, in these cases, instead of a few minims.

If the strong chloric ether were used exactly as recommended by Dr. Warren, there would, I fear, be danger of accident from a cause independent of the action of the vapour inhaled. An ounce of the medicine is directed to be poured on a sponge only twice the size of an egg, which must thereby be rendered dripping wet, and should the patient be on his back, there would be risk of some drops of the ether being drawn into the glottis, in a liquid form. I have been informed by the operator of a case in which a patient was threatened with suffocation from a drop of chloroform falling into the throat from a sponge, and the solution of it in alcohol is scarcely less irritating, and would undoubtedly cause spasm of the glottis.

It follows from the above considerations, that, as a general rule, there can be no advantage in using a mixture of two or more substances of different volatility, by any ordinary method of inhalation, since the mixture cannot be uniformly introduced into the circulation. If, however, it should hereafter be found that there is any physiological advantage in combining any vapours, they could easily be given together in any uniform proportion, by a method which I have been employing lately for the exhibition of chloroform in cases in which I wished to be more than usually precise, or to gain a more exact experience. This method consists in putting a definite quantity of the liquid to be inhaled into a balloon made of thin membrane, the capacity of which is known, and is not less than two thousand cubic inches, then filling the balloon with air by means of the bellows, and allowing the patient to inhale from it: the expired air being prevented from returning into the balloon, by one of the valves in the face-piece to which it is attached.

Part XII.

Further remarks on Dutch liquid—its chemical constitution — its physical properties—its narcotic power compared with that of chloroform—Cases of its administration in tooth-drawing, in midwifery, in cholera—Conclusions.

In a former paper* I gave an account of two or three experiments on small animals with Dutch liquid, by which it was shown that its narcotic properties were of a favourable kind, but that it caused inflammation of the lungs. This latter effect, as I have since ascertained, was occasioned by some impurity—probably sulphurous acid gas —in the specimen of Dutch liquid I then used. I made it myself, by getting the olefiant gas and chlorine to combine in a glass globe, as recommended in Fownes' Chemistry. The olefiant gas was passed through sulphuric acid to separate ether and alcohol, but the sulphurous acid was not separated from it, and I endeavoured to separate that and the hydrochloric acid from the products, when formed, by washing it two or three times in water, but did not succeed, as it since appears. On Mr. Nunnelly recommending Dutch liquid for inhalation last February, it occurred to me that neither the specimen which I had made, nor that used by Dr. Simpson, could have been pure. I accordingly made some more in the same manner as before, but washed it in a weak solution of carbonate of soda previous to distilling it from chloride of calcium. I now got a much less pungent substance,—similar, in fact, to that which I have since received from Mr. Morson and Mr. Bullock. On performing some experiments with it, I found that it possessed the properties which I previously described, with the exception of the irritant ones. I in-

* Vol. xlii. p. 331.

haled a little of it myself; but the process of making it being very troublesome and tedious, I had not enough to try its effects in practice till half an ounce was kindly given to me by Mr. Morson on the 20th March, which I used in four cases of tooth-drawing in St. George's Hospital, on the following morning. I have since received several supplies from Mr. Bullock, and have used it in a variety of cases; but, before I describe the results of its application, it will be more convenient to give an account of its chemical constitution, and of those of its physical properties which are intimately connected with its physiological action.

It was discovered in 1795 by the associated Dutch chemists, Bondt, Deiman, Vantroostwyk, and Lauwerenburgh. It is formed by the combination of two volumes of chlorine and two of olefiant gases. The latter, representing one atom, contains four atoms of carbon and four of hydrogen, and is considered to be a hydruret of acetyle,—acetyle being a hypothetic base consisting of four carbon and three hydrogen. When the two atoms of chlorine combine with the hydruret of acetyle, the following is, since the investigations of Regnault, believed to be what takes place. One atom of chlorine displaces an atom of hydrogen, and the hydruret of acetyle is converted into chloride of acetyle, whilst the other atom of chlorine combines with the displaced hydrogen, forming hydrochloric acid, and the two products at the same time uniting, hydrochlorate of chloride of acetyle is the result; and this is the chemical name of Dutch liquid in recent authors. This body is curiously connected with the discovery of chloroform, as was pointed out by Dr. Pereira in a communication on the history of the latter medicine.* Dr. Thomas Thomson, in the edition of his Chemistry published in 1810, gave the name of chloric ether to Dutch liquid, and stated that a solution of it in spirit was useful in medicine as a diffusible stimulant. Some years after this, Mr. Guthrie, a chemist in America, obtained a liquid by the distillation of spirit and water with bleaching powder, which he considered to contain the chloric ether of Dr. Thomson dissolved in spirit; and this product, which, in fact, consisted of chloroform and alcohol, was used for some time in medicine under the name of chloric ether. In 1831, Soubeiran found that this preparation did not contain Dutch liquid—the chloric ether of Dr. Thomson; and the following year Liebig also made an analysis of it; but, failing to discover the hydrogen in the chloroform, he considered that it was composed of chlorine and carbon; and after this time the medicine was often called ter-chloride or sesqui-chloride of carbon. There are various chlorides of carbon which have been discovered by Faraday and Regnault; but they are very difficult to make, and I believe that none of them have ever been on sale, either for medical or other purposes, and that the so-called chlorides of carbon which have been used in medicine were all of them solutions of chloroform, of which body Dumas was the first to ascertain the true nature and composition.

Dutch liquid is somewhat heavier than water, having a specific gravity of 1·247. It boils at 180° Fah. It is very sparingly soluble in water, and the specific gravity of its vapour is 3·4484. In sensible properties it very nearly resembles chloroform; and hence, probably, the reason of Mr. Guthrie, when he discovered the latter substance, mistaking it for Dutch liquid. The odour is not quite so fruit-like as that of chloroform, and the vapour feels less pungent; but the reason of this is that a smaller quantity of vapour is given off from Dutch liquid than from chloroform; for I find that when the two vapours are diluted to the same extent—for instance, till the air contain five per cent., and inhaled from a balloon, there is then no difference in the pungency. The physical properties of Dutch liquid which are most intimately connected with its narcotic action, when inhaled, are its volatility and solubility. From some experiments before related it was concluded that in the second degree of narcotism the blood contains one-fiftieth part as much as it would dissolve, and in the fourth degree one twenty-fifth part. These experiments have been repeated with the liquid quite free from impurity, and the results obtained were the same.

I have endeavoured to ascertain the solubility of Dutch liquid as accurately

* Med. Gaz. vol. xl. p. 953.

as possible, by admitting small quantities of water to air saturated with the vapour, and confined over mercury in a graduated receiver. The average of a number of experiments gives 1·7 volume of vapour as the quantity that one volume of water will dissolve; and, the liquid being 321 times as heavy as its vapour at 100°, it results that, at this temperature, one part of the liquid would require 189 parts of water to dissolve it.

If the average quantity of serum in the body be assumed to be the same as in treating of chloroform, and a calculation be made of the kind there given,* it will be found that the amount of Dutch liquid in the blood, in the second degree of narcotism, is rather more than twenty minims, and in the fourth degree forty-one minims. In the third degree the amount would be intermediate, viz. about thirty minims. These quantities are nearly twice as large as in the case of chloroform; and this agrees exactly with what I have met with in practice, since nearly twice as much Dutch liquid has been required to cause insensibility as would have been required of chloroform. To estimate the strength of this substance when inhaled, its volatility requires to be taken into account, in addition to the above data. Whilst 100 cubic inches of air at 60° will take up 14 cubic inches of chloroform, they will only take up seven cubic inches of Dutch liquid; and the vapour, moreover, is not so heavy as that of chloroform,—consequently it is not half so volatile. This makes the difference in strength between the two agents still greater. To exhibit more accurately their relative power, the quantity of air may be calculated that a patient would require to breathe, when saturated by either of the two vapours at 60°, in order to be rendered insensible. Eighteen minims is the average amount of chloroform in the blood in the third degree of narcotism, the stage usually required for a surgical operation, and as about as much is expired again without being absorbed, thirty-six minims is about the quantity inhaled before an operation. This would require only 257 cubic inches of air to take it up if saturated at 60°, the air becoming expanded to 294 cubic inches. Thirty minims of Dutch liquid require to be absorbed, as stated above, to induce the same amount of insensibility, and sixty minims would have to be inhaled. This quantity requires 904 cubic inches of air to allow it to be converted into vapour at 60°, the air being expanded to 967 cubic inches, an amount more than three times as great as requires to be inhaled in the case of chloroform; and consequently Dutch liquid has less than one-third the power of the former when inhaled in a similar way. Sulphuric ether is rather stronger than Dutch liquid—the quantity of air saturated with its vapour that is required to induce insensibility being rather more than 800 cubic inches.

For the reasons given above, Dutch liquid is much slower in its action than chloroform;* and whilst the chief endeavour in giving chloroform is to prevent the air from getting too strongly charged with the vapour, in giving Dutch liquid the endeavour is to get the air to take up sufficient of it. In one case, indeed, that of an infant in King's College Hospital, on which Mr. Fergusson operated for nævus, it failed to induce insensibility with the inhaler I was using (one contrived for chloroform), although continued for three or four minutes, and rather than cause further delay chloroform was used.

For reasons similar to those which render Dutch liquid slower in its action, when its effects are once produced they are more persistent than those of chloroform. Medicines so volatile as these escape from the system almost exclusively by the lungs; and as the quantity of Dutch liquid in the blood during insensibility is greater than that of chloroform, it would be longer in escaping, even if it could be exhaled at the same rate; but, being less volatile, it cannot. There is a continual tendency to equilibrium between the elastic force of the vapour in the blood and that in the air contained in the pulmonary cells: and if the blood contain, for instance, one-thirtieth part as much of a volatile liquid as it could

* Vol. xli. p. 850.

* A preparation consisting of equal parts of chloroform and spirit was fraudulently introduced into the drug-market last spring, and sold to a considerable extent as Dutch liquid, although not containing any of that body. This counterfeit liquid would cause insensibility with nearly the same rapidity as chloroform.

dissolve, each cubic inch of air which reaches the cells of the lungs is capable of taking up one-thirtieth part as much as would saturate it at 100°; but this quantity is twice as great in the case of chloroform as in that of Dutch liquid. The longer duration of the effects of the latter substance as compared with the former has been very marked in a number of experiments on animals, as well as in practice.

Although, as above stated, a greater quantity of Dutch liquid than of chloroform is required to induce insensibility in the first instance, yet in cases requiring the continued inhalation of the vapour there is but little difference in the amount used; since, from the more persistent effect of Dutch liquid, it does not require to be repeated so often.

The following are the cases in which I have tried the effects of Dutch liquid:—

1. On March 21, 1849, a young woman, about 25 years of age, inhaled it, in the out-patients' room of St. George's Hospital, previous to having a tooth drawn. She was nervous and hysterical, and was alarmed at the inhalation, although very anxious to avoid the pain. She inhaled from the apparatus described before,* between one and two minutes, when she strongly requested to leave off. The tooth, a first lower molar, firmly fixed, was immediately extracted with the forceps by Mr. Parkinson, dresser to the surgeon for the week. The patient cried out slightly as the tooth came out. She said afterwards that the removal of the tooth did not hurt her so much as the lancing of the gum on a previous occasion. In a few minutes the partial stupor caused by the vapour had subsided. This patient was not rendered quite unconscious, but the sensibility, and consequently the pain, were apparently diminished.

2. Another young woman inhaled the Dutch liquid immediately afterwards. She breathed it very steadily. The pulse became increased a little in frequency and force soon after she began to inhale, and the face at the same time became slightly flushed. There was no further symptom, and no alteration in her appearance till nearly four minutes had elapsed, when voluntary motion ceased in the eyes and eyelids, and the pupils were turned upwards. The inhalation was now discontinued when she had inhaled just four minutes. The muscles of the jaw were rather rigid, but the mouth was easily opened by making a little pressure on the chin, and a bicuspid tooth was extracted with the forceps by Mr. Parkinson, without causing the least flinch, cry, or altered expression of countenance on the part of the patient. Immediately after the tooth was extracted she opened her eyes, looking bewildered at first, but in one minute after the inhalation ceased she regained her usual expression, and began to wash out her mouth. She said that she had felt nothing. Three minutes afterwards she left the hospital feeling well. The narcotism, in this case, just reached the third degree, and there was complete immunity from pain, as indeed there generally is under the effects of chloroform carried to the same extent, when it is inhaled slowly. The recovery was as prompt as it usually is from chloroform; but it should be noticed that when the inhalation of that vapour is left off just when the symptoms reach the point indicated in the above case, the patient usually begins to recover immediately, even before there would be time to extract a tooth. Two fluid drachms of Dutch liquid had been put into the inhaler, and it was not quite all used by these two patients. A drachm more was added when the next patient commenced to inhale.

3. This patient was a labouring man, between 30 and 40 years of age. Soon after beginning to inhale he commenced to laugh, and he kept the corners of his mouth stretched so widely apart that it was difficult to make the face-piece fit exactly. In about five minutes he appeared to have lost his consciousness, and he muttered incoherently. He soon afterwards became unruly, and was with difficulty kept in the chair. The conjunctiva remained sensible, and he flinched when a hair of his face was pulled. Although he inhaled a few minutes longer, he did not become further affected; the reason of this being, as I afterwards found, that the Dutch liquid in the inhaler was finished. There was great difficulty in getting the mouth open, not from spasm but from voluntary resist-

* Vol. xlii. p. 843.

ance exerted under the influence of some obscure dream. The patient flinched as the tooth was extracted; but on recovering his consciousness two or three minutes afterwards, he said that he had felt nothing. The truth probably is, that the feeling had been obscure, and there was no recollection of it. He complained, however, of giddiness, and began to look pale and sick. In a few minutes he vomited, and then complained of headache. He was complaining of headache and sickness half an hour afterwards, when I left him, expecting that these symptoms would soon subside. But I afterwards found that they continued so severe, with occasional vomiting, that he was kept in the hospital till the following morning, when he left, but came back in the forenoon, complaining that he could not go on with his work. Mr. Hammerton ordered him some medicine containing ammonia, and directed him to return the next morning if he should not feel well. He did not apply again.

This is the only case in which I have seen Dutch liquid followed by distressing sickness or headache; and the result might have been the same if chloroform or ether had been used, as such symptoms do now and then follow their use, though rarely to the same extent as in this case.

4. In the above cases the water bath of the inhaler was at the temperature of 60°; in this case it was raised to 70°. Fifty minims of the medicine were put into the inhaler, and a little girl, six years old, inhaled for two minutes. At the end of this time she became insensible, the pupils of the eyes being turned upwards. A decayed molar tooth was extracted without causing the least flinch or cry. In about a minute after the inhalation ceased, the child became conscious, but staggered on attempting to walk. She vomited a little, two or three minutes after this, but in a few minutes more was free from sickness, and pretty well. The fifty minims were not all consumed by this patient.

5. The subject of this case was a patient of Mr. Marshall, of Greek Street, in labour with her second child, on April 24. I exhibited twenty minims of Dutch liquid (all I had with me at the time) during the last three or four pains which expelled the fœtus. The patient ceased to complain, but continued her expulsive efforts. She was not rendered quite unconscious, but her sufferings were greatly alleviated, being, as she said afterwards, much less severe than before, whilst without the inhalation they would have been much greater. Mr. Marshall was present and attending to the labour. In this and the next three cases the vapour was administered by means of a small inhaler, which I commonly use for giving chloroform in midwifery cases; it consists of the same face-piece which forms part of my other inhalers, and of a short curved metallic tube, lined with bibulous paper.

6. Having expressed a wish to Dr. Murphy, Professor of Midwifery in University College, to try Dutch liquid in some cases of labour, I was called on by him on the day on which the last of the above cases occurred, and accompanied him to a patient of Mr. Jakins, of Osnaburg Street, who had been forty-eight hours in this, which was her first labour. Dr. Murphy, who is about to give the particulars of this and the next case to the profession, found it necessary to divide a thick dense band, extending across the vagina, and also to make an artificial os uteri, and deliver with the forceps. Half a drachm of the liquid being inhaled, it gradually induced a state of unconsciousness, during which the speculum vaginæ was introduced; the uterine contractions and slight expulsive efforts continued as before. A little more Dutch liquid was put into the inhaler, from time to time, so as to keep the patient unconscious. The pupils of the eyes were turned upwards during part of the time. No mental excitement or muscular rigidity was occasioned. Dr. Murphy proceeded to make an artificial os uteri, and to divide the ligamentous band. These operations were partly performed when my stock of Dutch liquid, about three fluid drachms, was all used. It had kept up insensibility for about an hour. Chloroform was now given, so as to keep the patient constantly insensible to the end of the delivery. There was little appreciable alteration in the symptoms on passing from the use of one vapour to that of the other. The effects induced were of the same kind, but they were produced with much less inhalation in the case of chloroform;

a few inspirations, now and then, with the valve partly open, sufficed instead of the previous more lengthy inhalation, with the valve closed. The delivery was effected with the forceps about an hour after the inhalation of chloroform commenced, half a fluid ounce of which was used, being a larger quantity than was used of Dutch liquid in the same period; but the patient was kept more deeply insensible during the whole of this latter period than in some part of the first hour, when the operation had not yet commenced. The child was born alive, but breathed feebly, and died next day. The placenta was expelled without hæmorrhage a few minutes after the birth of the child. The patient was quite conscious ten or fifteen minutes after the inhalation was discontinued; and after being bandaged and placed in a comfortable posture, she fell asleep, and slept almost uninterruptedly for twelve hours. She recovered very favourably.

7. On May 18, I administered the Dutch liquid at the request of Dr. Murphy, to a primipara, 35 years of age, who had been 48 hours in labour, when he resolved to deliver with the forceps. Half a drachm was put into the inhaler: the patient objected to the vapour at first, on account of its pungency, but afterwards inhaled readily, and in about two minutes appeared unconscious, the pupils being turned upwards, and the eyelids firmly closed, and resisting the attempt to open them. Dr. Murphy now began to introduce the forceps, and the patient cried out a little: another half drachm of the liquid was put in, and she soon became quiet, and was kept insensible till the birth of the child, which was effected in less than half an hour. She talked in a rambling manner about some ordinary topic once or twice during the inhalation, and also a few minutes after it was discontinued. Two fluid drachms were used in all. The placenta was expelled ten minutes after the birth of the child; soon after this the patient vomited; and fifteen minutes after the birth (the time when the inhalation was left off), the patient began to regain her consciousness. She recovered very favourably, and the child is living.

8. The Dutch liquid was administered in a case of cholera that Mr. Marshall, of Greek Street, requested me to see with him. The patient was a child seven years old, which had been ill twelve hours. The stools were copious and watery, and devoid of fæcal colour or odour; the vomiting was constant and severe; the features were sunken, and the pulse was about 160 in the minute, and so feeble as to be felt with difficulty. There were jactitation and great uneasiness, the latter probably resulting from cramps. Twenty minims were inhaled, which produced a state of unconsciousness and quiet, from which the little girl awoke in ten minutes. The same quantity was again inhaled, with a like effect, and of rather longer duration. The pulse was improved by the inhalation, being rendered stronger and less frequent; but the chief symptoms of the disorder went on as before. The child recovered.

The relief from inhalation of chloroform in cholera has generally been greater than this in the cases I have witnessed, the unconsciousness having generally merged into a natural sleep, of from half an hour to two hours and a half in duration, during which time of course the patients were free both from sickness and spasm. Two of the cases were also under the care of Mr. Marshall. I attribute the different action in the above case to some difference in the state of the patient, rather than in the properties of the narcotic.

9. On July 18, a boy, nine years old, inhaled Dutch liquid in the out-patients' room of St. George's Hospital, from the balloon described in my last communication. Each hundred cubic inches of air in the balloon contained four minims of the liquid, or a small fraction over four cubic inches of the vapour. In two minutes consciousness was removed; he then began to resist the further inhalation, but with a little trouble was got to inhale two minutes longer. He was not narcotised beyond the second degree. Voluntary motion was never abolished, but the sensibility of the conjunctiva was diminished. Two incisor teeth of the first set were extracted without being felt (probably without the inhalation there would have been no great pain). He was laid on the bed, and in two minutes recovered his consciousness, but staggered on getting up. In about ten minutes the effects of the vapour had

apparently gone off. He inhaled about 1000 cubic inches, and consequently 40 minims of Dutch liquid; this quantity of chloroform would have rendered an adult of twice his weight fully as insensible as he was, if not more so.

The result of my observations and investigations is, that I cannot unite with Mr. Nunnelly in his general praises of Dutch liquid. The only advantages which it possesses over chloroform, in any case, are such as are connected with its slower action and more persistent effects, — properties that Mr. Nunnelly failed to recognize. In all other respects its effects appear to be the same as those of chloroform. It is undoubtedly a very safe anæsthetic; but I doubt very much whether practitioners would be content to wait for its slower action, after they have been accustomed to use chloroform, even if it could be obtained at the same cost, of which there is no prospect. In whatever way Dutch liquid might be used, it would not suddenly occasion a fatal accident without giving due warning; in this respect it resembles ether. Advantage might be taken of its more persistent effect in some operations in the face, in which it is difficult to administer a vapour after the surgeon commences; and also in cases in which the operator is without an assistant, and has to make his patient insensible first, and then to perform his operation. In obstetric practice it would perhaps be more convenient than chloroform, when only one medical man is present, as he might intrust the inhaler to the nurse, and look up two or three times in a minute to give directions; but when there is a practitioner entirely to superintend the inhalation, chloroform has the advantage, as it can be given to the requisite extent just as each pain commences, and the patient can be allowed to recover from its effects, more or less, between every pain.

Part XIII.

Action of Alcohol compared with that of Chloroform and Ether.

Experiments on frogs with alcohol—On fishes, with alcohol, chloroform, and ether—Quantity of alcohol necessary to cause drunkenness—To cause death. Anæsthetic effects of alcohol—Liebig's views of the action of alcohol—their application to ether and chloroform—Objections to these views.

I FEEL that I ought to apologise to the readers of the MEDICAL GAZETTE for the great length of time that has been allowed to elapse before the completion of these papers. The delay has not arisen from any want of anxiety on my part to bring the subject to a conclusion, but from finding, as I proceeded with it, that it was desirable to repeat many experiments and institute fresh ones, the performance of which occupied a great deal of time.

In order to enter on the investigation of the *modus operandi* of ether and chloroform with every advantage, it is desirable to ascertain whether or not alcohol, which, in its chemical constitution and general physiological properties, considerably resembles these medicines, is identical with them in its action. It was previously stated* that alcohol, pyroxilic spirit, and acetone, which are miscible with water in all proportions, confirm the general rule then laid down, that the power of volatile narcotic substances of the class we are considering is in the inverse ratio of their solubility, as a large quantity of the above three liquids requires to be taken to produce narcotism. It afterwards occurred to me that experiments might be instituted to ascertain whether alcohol and the other two liquids obey exactly the law which we found to apply to chloroform, ether, and a number of other bodies. Experiments to determine this point could not easily be made on animals that breathe air exclusively, on account of the length of time that the vapour would continue to be absorbed; but, by employing frogs and fishes, the end could be attained. In the experiments previously related, it was found that the second degree of narcotism was caused when the serum of the blood contained about a fifty-sixth part as much of the chloroform, ether, or other substance examined, as it would hold in solution. Now, if the rule apply to alcohol, the second degree of narcotism ought to be induced when the amount of spirit is equal to one fifty-sixth of the volume of the serum.

The following are some of the expe-

* Vol. xlii. p. 333.

riments undertaken to determine this point.

Exp. 47.—A frog was placed in a shallow glass jar, capable of holding a pint. Seven ounces of water, mixed with a fluid drachm and a quarter of rectified spirit of wine, were put into the jar. The spirit consisted of 80 per cent. absolute alcohol, of which it consequently contained one drachm; and, as there are fifty-six drachms in seven ounces, the water contained one part of alcohol in fifty-six. It was the early part of March; and the frog, although quite sensible, was not very lively. When enclosed in the jar, it sat, with the head above the water, breathing the air at the rate of ninety respirations in the minute. As the jar was covered by a plate of glass, the air it contained would soon become charged with vapour of alcohol to the same relative extent as the water; that is to say, it would contain 1-56th part as much as if saturated at the same temperature, and the tendency of the absorption, by both the lungs and skin of the frog, would be to establish an equilibrium between the quantity of alcohol in the fluids of its body and that in the surrounding water, when the blood of the frog would consist of about 1-56th part spirits. Two hours after the commencement of the experiment, the strength of the frog appeared to be diminished, and it had a difficulty in keeping its nostrils above the water. It was breathing irregularly, and much less frequently than before. At the end of four hours its head was under the surface, and it was not breathing. Being taken out for a minute or two, it moved its head and limbs feebly, but apparently in a voluntary manner, but did not attempt to breathe. It was replaced in the jar, and left for the night, with its head beneath the surface, the jar being covered as before. The next morning, twelve and a half hours from the beginning of the experiment, the frog was found with its nostrils slightly raised above the surface of the spirit and water, and breathing gently and slowly. Being taken out, it was found to flinch slightly on the skin being pinched, and was able to crawl slowly, chiefly by the use of the anterior extremities. It recovered perfectly in the course of the day. The temperature of the room during this experiment was 50 Fahr.

Exp. 48. Another frog was placed in the same jar, with seven ounces of water, containing two and a half fluid drachms of the same spirit, the strength being consequently one part of alcohol in twenty-eight parts. In about an hour and a half the frog seemed feeble, and had difficulty in keeping its nostrils above the surface. At the end of two hours, its head had sunk beneath the surface, but the respiratory movements were going on, though feebly, and it seemed to be swallowing the liquid. At the end of three hours the lower jaw had fallen, and the mouth was open, but there were slight respiratory movements of the hyoid bones. There were feeble muscular twitches (subsultus tendinum) observed occasionally. A support was at this time placed under the anterior extremities of the frog, to keep its head above the surface of the water. It was found to be totally insensible to pinching. Its mouth continued open, and the feeble respiratory movements went on. At the end of five hours it was breathing very gently, and very slight twitchings of the toes could be observed occasionally. Seven hours and a quarter from the commencement of the experiment, the respiration had ceased. The frog was taken out, and showed no signs of life at first; but, on closely observing it, slight quivering movements of the toes, and of different parts of the muscles just beneath the skin, could be seen It was exposed to the air in a shallow dish containing a very little fresh water. In two hours after its removal, feeble respiratory movements could be occasionally observed. The breathing gradually became quite re-established, and seven hours after its removal it had recovered both sensibility and voluntary motion. The next day it seemed pretty well, and had resumed its colour, having been rendered nearly black whilst narcotised. The other frog also became much darker in colour, whilst under the influence of the spirit, in the previous experiment.

In the former of the above experiments the frog appeared to be in the second degree of narcotism, sensibility and voluntary power being impaired, but not abolished. In the last experiment the narcotism reached, and apparently rather exceeded, the fourth degree. The effect produced was nearly the same as that caused by one twenty-sixth part as much chloroform as the blood would dissolve, in one of the frogs,

the subject of Experiment 15, formerly related; and rather more than the effect produced by one thirty-second part as much ether as the blood would dissolve, in a frog used in Exp. 28.

Exp. 49.—The frog employed in Exp. 47, being in good health, was, four days afterwards, placed in the same jar with nine ounces of water, containing five fluid drachms of rectified spirit of 80 per cent., equivalent to half an ounce of absolute alcohol; the proportion of alcohol being, consequently, one in eighteen of the mixture. At first the frog made some attempts to get out. At the end of seven minutes it withdrew its head volmtarily beneath the surface, and ceased to breathe; but two or three minutes afterwards it raised it again above the surface, and breathed the air. Twenty minutes from the commencement, it appeared to have a difficulty in keeping its nostrils above the surface, and now and then made an abortive attempt to leap up. The eyelids were half closed, and the cornea looked dim. At the end of half an hour it was lying on its belly without any sign of life. A support was placed under it to keep its head above the surface, and feeble respiratory movements recommenced. Three quarters of an hour from the beginning of the experiment, the respiration had entirely ceased, and no external sign of life remained. It was left an hour longer in the jar, and was taken out after being exposed to the spirit and water, and the vapour given off from it, for an hour and three quarters. No pulsation of the heart could be observed externally, but on removing a portion of the integuments and sternum with the scissors, the heart was found to be pulsating feebly. The frog was placed again in the spirit and water, being laid on its back, so that the heart could be observed. It was noticed to continue pulsating feebly for half an hour. Being left for two hours, it was found at the end of that time that the action of the heart had entirely ceased. As only one or two drops of blood were lost in exposing the heart, and as frogs at the temperature at which this experiment was performed (52° Fah.) can live almost altogether without the pulmonary respiration, it is probable that the action of the heart was arrested by the narcotic effect of the alcohol; and it was found in experiments 42 and 43, formerly related, that one eighteenth part as much of the vapour of chloroform as the blood would dissolve, had the effect of arresting the action of the heart in frogs.

Exp. 50.—Two fluid drachms and a half of rectified spirit, equivalent to a quarter of a fluid ounce of absolute alcohol, were mixed with sufficient water to make up fourteen ounces, which, consequently, contained one part of alcohol in fifty-six parts. This was put into the glass jar before used, and a small gold fish, weighing two drachms and a half, was put in. The jar was covered, to prevent loss of spirit by evaporation. After a few minutes the fish seemed rather more active than before it was put in. At the end of twenty minutes it no longer regarded, or was frightened by, any object touching the jar, and it began to oscillate from side to side in swimming, and to incline to one side when still. Half an hour from the beginning of the experiment it was swimming very much on its side. It did not become appreciably more narcotised, although it remained in the water and spirit until two hours had expired. It struggled whilst being romoved into fresh water. In half an hour after its removal it had partially recovered, and when next observed, two or three hours later, it was in its usual state.

Exp. 51.—Another small gold fish, weighing rather more than three drachms, was placed, in the same manner, in water containing one twenty-eighth part by measure of alcohol. In less than ten minutes the fish began to move about violently. Soon afterwards these movements became irregular and ill directed, the fish being unable to preserve the perpendicular position, and it no longer observed objects brought close to the jar. It continued, every now and then, to move about violently, and somewhat convulsively, till three quarters of an hour had expired, when it became quieter, floating on its side, and moving only occasionally. The opercula moved, but not regularly. At the end of an hour it had ceased to move its body and fins altogether, and a few minutes later it was found that the opercula did not move. It was placed in fresh water, and in a few minutes the opercula began to move, at first at long intervals, but in half an hour the respiration was regular, and the fish was beginning to move its body. The next morning it appeared quite well.

In Exp. 50 the fish was in the second degree of narcotism, and in the last experiment there was complete insensibility, and the fish would soon have died, probably not from absorption of additional spirit, but because the utmost extent of narcotism cannot be long continued without extinguishing the vital powers.

In some experiments with pyroxilic spirit, or wood naphtha, the same effects were produced on fishes, when it was mixed with water in the same proportion as the alcohol in the two last experiments; but the fishes died several hours afterwards, through the poisonous action of the naphtha, having first, in a great measure, recovered their sensibility and voluntary power.

The two following experiments are introduced for the purpose of showing that chloroform and ether act on fishes in the same way as on other animals.

Exp. 52.—Six fluid drachms of water in a small evaporating dish were placed on a plate of glass, by the side of a small dish containing chloroform; the two dishes were covered by a bell-glass, ground at the edge, to fit air-tight on the glass plate, and left till the next day, in order that the water might be saturated with chloroform, by absorbing it in the form of vapour. As soon as the bell-glass was removed, the small dish of water was put quickly into two pints of water, in which a gold fish was swimming, in a glass jar capable of holding three pints, and the jar was covered to prevent loss by evaporation. In ten minutes the fish began to oscillate a little in swimming. At the end of twenty minutes it was swimming frequently on its side, and then again recovering its balance. Half an hour from the beginning of the experiment the fish floated for a minute or two on its side, at the surface of the water, without moving its body or fins; then it began to swim about again for a time, and it continued occasionally to move for a short time, and then again to appear lethargic, until it was removed and put into fresh water, three hours after the commencement of the experiment. It struggled a little whilst being lifted out of the water. In an hour it had in a great measure recovered, and next day was as well as before. The water saturated with chloroform composed a fifty-fourth of the whole, which consequently contained one fifty-fourth part as much chloroform as it would dissolve, and the fish was in the second degree of narcotism.

Exp. 53.—A fluid drachm of ether was mixed with two pints of water, and a gold fish put into it, and the jar was covered, as in the former experiment. As water is capable of dissolving one-tenth of its volume of ether, the water in this experiment contained one thirty-second part as much as it would dissolve. The fish was but little affected during the first hour, but at the end of an hour and a half it inclined to one side in swimming. When two hours had elapsed it was floating completely on its side, and had ceased to move its fins. It was taken out and put into fresh water. It moved a little on being handled. In about ten minutes it began to swim, and the effects of the ether gradually and completely went off.

As the deeper degrees of narcotism cannot be long continued without dangerously depressing the vital actions, so, with an agent whose effects last so long as those of alcohol, a state of complete coma cannot be induced at all without risk, especially if the body be exposed to a low temperature. Ordinary drunkenness does not exceed the second degree of narcotism; the popular term of dead drunk being often applied to a state of sleep from which the individual is still capable of being roused to a state of incoherent consciousness. In order to estimate the quantity of spirit that would be required to induce the second degree of narcotism in a man having the average amount of blood, 410 fluid ounces, which were taken as the amount of serum in the body in the earlier parts of this article, may be divided by 56, which will give seven ounces one drachm, a quantity of alcohol equal to rather more than fifteen ounces, or three-quarters of a pint of proof spirit. This is a quantity which, I believe, agrees pretty well with general experience. Less than twice this amount, if taken all at once, and on an empty stomach, so as to be quickly absorbed, ought, according to the above considerations, to prove fatal; and there have been many instances of such a result.

A few years ago a man drank a bottle of gin, in the Haymarket, for a wager. He was soon in a state of profound insensibility, and the late Mr.

Read, the instrument maker, informed me that when he applied the stomach-pump at the police station, in the presence of a medical gentleman, the stomach was found to be quite empty. The man shortly afterwards died. The quantity of absolute alcohol in a bottle (twenty-four ounces) of strong gin is about thirteen ounces. In the fifth case in Dr. Ogston's paper on intoxication,* a woman lost her life by drinking less than a bottle of whiskey; and I believe that it is only by dividing the dose, and thus distributing its effect over a longer time, that any person can, with impunity, take a quantity of spirit exceeding this. The two bottles of wine which, when drinking was less unfashionable than at present, some persons could take after dinner, without being rendered altogether incapable, would contain, according to Mr. Brande's table, from nine to twelve ounces of alcohol; but this quantity was consumed during a protracted sitting, and after eating food, which would further retard its absorption. The difference in susceptibility to the influence of alcohol, though existing to some extent, is not so great as it appears to be. The real difference is more in the way in which the mind is affected by it. A person who is excited evinces the effects of a moderate quantity, which are not so apparent on one who is not excited; whilst to make both individuals quite insensible, the quantity, as in the case of ether or chloroform, would probably not differ more than the size of the individuals, or rather the quantity of blood they might contain. With respect to the large amount of wine and spirits that patients in a state of extreme debility sometimes take without being apparently intoxicated, the following remarks may be made. Such persons are usually incapable of showing excitement under the influence of narcotics; and, as the alcohol is given in divided doses, which are insufficient to cause insensibility or coma, the effects which are really produced pass unnoticed. Long habit has some effect in enabling a person to take a larger quantity of alcoholic liquor: this, however, does not arise altogether from the diminished action of the spirit, but partly from experience of the muddled condition, which enables him to control his actions to some extent, and to go about his affairs with a sort of sober aspect when very unfit for business. The woman whose case is quoted above, and who was killed by less than a bottle of whiskey, was a drunkard; and, at all events, the habit of drinking alcohol has no power of enabling persons to increase the dose in the extraordinary manner in which that of opium can be increased.

The amount of anæsthesia from alcohol is apparently as great, in proportion to the narcotism of the nervous centres attending it, as from chloroform and ether. A case occurred in King's College Hospital illustrating this. On Thursday night, the 21st of December, 1848, Mr. Fergusson performed amputation of the leg on an elderly man who had just before sustained a bad compound fracture. The man was very drunk, and Mr. Fergusson informed me that he evinced but little feeling, and did not seem aware of what was being done. He called out once during the operation that he had the cramp in his leg. When I questioned the patient a day or two afterwards, he said that he did not remember anything of the operation, and he supposed that chloroform had been administered to him. This, however, was not the case. Alcohol does not yield sufficient vapour, at ordinary temperatures, to cause insensibility by inhalation in a reasonable time; but, if no better means had been discovered, there can be no doubt that it would have been both practicable and allowable to prevent the pain of severe operations by getting the patient to swallow a large quantity of spirit and water. The end would have justified the means, and, in fact, rendered it as praiseworthy as it is disgraceful when resorted to for the purpose of supposed enjoyment, or to satisfy a craving which has resulted from a pernicious habit.

The general tendency of physiological researches had for some time been to prove that all the strictly animal functions resulted from the combination of the oxygen of the air with the constituents of the body, when Liebig* stated the position more fully and clearly than, as I believe, had previously been done. His attempted explanation of the physiological action of alcohol, which many persons were inclined to extend to that

* Edin. Med. and Sur. Jour. vol. xl.

* Animal Chemistry.

of ether, on its introduction for inhalation, is in accordance with these views, and is to the following effect*:—That, according to all the observations hitherto made, neither the expired air, nor the perspiration, nor the urine, contains any trace of alcohol after indulgence in spirituous liquors†; that the elements of alcohol combine with oxygen in the body, and that its carbon and hydrogen are given off as carbonic acid and water; that the elements of alcohol appropriate the oxygen of the arterial blood, which would otherwise have combined with the matter of the tissues, or with that formed by the metamorphosis of the tissues: and that thus the change of the tissues, and the muscular and other forces which would result from that change, are diminished. Whilst it may be admitted that alcohol diminishes the change of tissues and the functions connected with these changes, and will, indeed, be shown further on that this is true with regard also to the narcotic vapours treated of in this article, it can readily be proved that it is not by appropriating the oxygen in the blood that this diminution or suspension of the molecular change of tissues is effected. The following, amongst other considerations, show this:—First, the carbon and hydrogen of fat, starch, sugar, and gum, as Baron Liebig had the merit of showing, combine with oxygen in the blood, and are given off as carbonic acid gas and water; yet these substances are in no degree narcotic. Second, the carbon and hydrogen of chloroform, which in the laws of its action is almost, if not quite, identical with alcohol, could not possibly combine with oxygen sufficient to act in the way supposed. The amount of carbon and hydrogen in twenty-four minims of chloroform—the quantity which, as it was estimated on a previous occasion, exists in the blood of the adult in complete insensibility,—is only about four grains: an amount totally insignificant when compared to the oxygen which is continually absorbed in the lungs. And, third, if alcohol and the agents allied to it acted by appropriating the oxygen in the arterial blood, breathing air richer than usual in oxygen ought to prevent or arrest their narcotic action. But such is not the case: breathing even pure oxygen does not remove intoxication, or prevent or remove the effects of narcotic vapours. The latter point I have ascertained as regards both the human subject and inferior animals, and have seen insensibility kept up in an animal by the ordinary amount of ether vapour, whilst its skin was of a bright vermilion colour, from the excess of oxygen in the blood.

* Ibid. p. 239.

† This we shall afterwards find to be incorrect.

Part XIV.

Chloroform passes off unchanged from the blood, in the expired air—Its detection in the urine—in the dead body—in an amputated limb—Remarks on the process for its detection.

At the end of the last paper, reasons were given for concluding that the effects of narcotic vapours were not due, as some had supposed, to the hydrogen and carbon they contain, combining with the oxygen of the air dissolved in the blood; and evidence was adduced to show that if such combination do take place, this would not explain their narcotic action. It still remained desirable to determine by experiment, if possible, whether these bodies are decomposed in the system, or pass off unchanged in the breath, or in other ways. With this view the following experiment was performed:—

Exp. 54.—Ten minims of chloroform were put into a hydrogen balloon, holding 300 cubic inches. The balloon was filled up with air, which I breathed backwards and forwards, in the way in which nitrous oxide gas is taken, for probably about two minutes. The word probably is used, because, after observing the watch for a minute and a half, I lost the recollection of what I was doing, and on recovering so as to observe the watch again, I found that another minute had elapsed, and that I had carefully lain aside the balloon in the meantime. Half a minute after this, and three minutes after beginning to inhale, I commenced to pass the expired air through a tube of hard glass, which was placed in readiness in a charcoal fire. To the further end of the tube were fitted other tubes connecting it with two Woolfe's bottles, each containing a solution of nitrate of silver. The respired air was taken in by the nostrils and breathed out by the mouth, passing first through the red hot tube, and afterwards through the solutions of nitrate of silver. This process was continued for four minutes.

The solution was rendered turbid, more especially that in the first bottle; being at first white, but shortly afterwards of a dark violet colour. At the end of twenty-five minutes from the inhalation, and when scarcely any appreciable effect of the chloroform remained on the feelings, I again breathed the expired air through the red-hot tube, the Woolfe's bottles having been removed, and a small tube moistened inside with solution of nitrate of silver having been attached. A slight precipitate of chloride of silver immediately appeared in the tube. The precipitate in the Woolfe's bottles having been washed and dried on the filter, was found to weigh 1·2 grain.

I have on other occasions, after inhaling chloroform, made the expired air to pass at once through a solution of nitrate of silver without the intervention of the red-hot tube, when not the least precipitate was occasioned; consequently, the chlorine which combined with the silver in the above experiment was the result of the decomposition of chloroform in the hot tube, and not in the circulation. As upwards of half a minute was allowed to elapse, during which several inspirations were taken between the conclusion of the inhalation and commencing to breathe through the tube, the lungs must have been completely emptied of the air taken from the balloon, and the vapour of chloroform must consequently have been exhaled from the blood. The further part of the experiment, performed twenty minutes later, more strongly proves this, and also shows that chloroform continues to be exhaled as long as any appreciable effects of it remain.

If all the chlorine of the chloroform united with the silver, the quantity of chloride obtained in four minutes, in the above experiment—viz. 1·2 grain, would indicate only 0·476 grain of chloroform. But I have found that on passing the vapour of a known quantity of chloroform through a red-hot tube, only about one-third of the chlorine is liberated, chiefly in the form of hydrochloric acid gas, and combines with the silver, as will be more fully explained further on: consequently, the above quantity of chloride of silver may be taken to indicate 1·428, or nearly a grain and a half of chloroform. It would not be easy to continue to test for the whole of the vapour exhaled by the breath. Indeed, breathing through the tubes and liquids for four minutes, in the above experiment, was attended with some inconvenience. But when it is considered that part of the chloroform used must have remained in the balloon, that a further part must have been exhaled before beginning to breathe through the red-hot tube, and that the vapour was still being exhaled twenty-five minutes after the inhalation, the experiment must help to confirm the view that by far the greater part of the chloroform inhaled is exhaled again by the breath.

It is probable that a small portion of chloroform passes out by other channels than that of the expired air: the latter, however, offers such a ready and expeditious outlet, that the quantity excreted in any other way is, most likely, very minute. I have on four occasions examined urine passed after the inhalation of chloroform, by boiling it in a flask, and passing the vapour, first through a red-hot tube, and afterwards through a tube moistened inside with solution of nitrate of silver, and I only on one occasion obtained a very slight precipitate of chloride of silver.

The presence of chloroform can be detected in portions of the body removed by the surgeon, when the patient is under its influence, and in the bodies of animals killed by it. And as this part of the subject is interesting in a medico-legal as well as in a physiological point of view, I shall enter a little more minutely into the account of it than I might otherwise have done. In the Journal de Chemie Médicale for March, 1849, a process for the detection of chloroform in the blood is described in the following terms:—"In order to recognise the presence of chloroform in the blood, we take advantage of the property which this body possesses of being decomposed at a red heat, in giving rise to chlorine and hydrochloric acid. In order to perform the operation, it is sufficient to boil an ounce of blood for some time in a glass flask over the water bath. The vapour must pass through a tube heated to redness at one part, and of which the extremity is smeared interiorly with a mixture of iodide of potassium and paste of starch. A strip of paper moistened with the same mixture may also be put into the tube. If any chlorine be produced by

the decomposition of chloroform, the strip of paper will be turned blue. In this way one part of chloroform in 10,000 of blood may be discovered." It is not stated in this article whether the chloroform detected had entered the blood during life, or had been added after its removal, though the former was probably meant

In employing this process I substituted solution of nitrate of silver for the starch and iodine test, considering that to obtain some of the chlorine as chloride of silver would be more satisfactory, in a medico-legal point of view, than merely showing the presence of something which decomposes the iodide of potassium. I find, also, that the nitrate of silver possesses other decided advantages. In the first place, it is a much more certain and delicate test. The iodine test is not acted on by hydrochloric acid, but only by the free chlorine, very little of which is produced by passing the vapour of chloroform through a red-hot tube, and that not constantly. Again, if there be a trace of chlorine to set free a little of the iodine, a little warm vapour, which is very apt to rush through the tube, whilst it does not affect the chloride of silver, may either prevent the blue colour of iodide of starch being developed, or suddenly discharge it, as I have seen. And lastly, the nitrate of silver test allows of a quantitative analysis being made, whilst the other does not admit of it. Dr. Alfred Taylor has, however, suggested to me to combine the two tests with a third one, by introducing a slip of starch paper moistened with solution of iodide of potassium, and also a slip of blue litmus paper, into another part of the tube, where it is not wet with the nitrate of silver. Used in this way, these additional tests may tend to confirm the evidence, and to meet objections that might possibly be made to the nitrate of silver test when used alone.

Before relating the experiments in which the presence of chloroform was detected in the body, it will be preferable to give some account of the decomposition which takes place when the vapour of that substance is passed through a red-hot tube. Soubeiran, when treating, in 1831,* of the body afterwards named chloroform, said, that on passing it, in the form of vapour, through a tube of porcelain filled with small fragments of porcelain, and made red-hot, that a good deal of charcoal is deposited, and that a gas is produced formed almost entirely of hydrochloric acid; and that there is found besides a very small quantity of chlorine and of an inflammable gas. He added, that, unless the pieces of porcelain are so arranged in the tube as to delay the passage of the vapour, without obstructing it too much, there is more chlorine liberated, and a substance left in the tube which stains paper like an oil. Liebig* says of chloroform, "when its vapour is passed through a red-hot tube it is decomposed into carbon, hydrochloric acid, and a crystalline body which appears in long white needles." On another occasion† he says that this crystalline body is probably the perchloride of carbon discovered by Mr. Faraday.

I performed the following experiments with a view more particularly to ascertain whether any appreciable quantity of free chlorine is produced during the decomposition of chloroform at a red heat:—

a. Ten grains of chloroform were put into a dry retort, made out of a small green glass tube, and capable of holding only a drachm. The retort was heated gradually in the water bath. Its beak was kept red-hot by the flame of a spirit lamp, and communicated with two Woolfe's bottles, containing solution of nitrate of silver. Charcoal was deposited in the beak of the retort at the part where it was red-hot: half an inch from this part, on each side, there was a copious deposit of long, white, needle-shaped crystals, and, after a time, a reddish-brown oily-looking liquid appeared. The precipitate of chloride of silver, which was found almost exclusively in the first bottle, weighed, after being washed and thoroughly dried, 12·5 grains.

b. Ten grains of chloroform were put into a similar retort and treated in the same way, except that the beak of the retort opened under a receiver in the mercurial trough. The deposits in the tube of the retort were the same as before, and 9.15 cubic inches of gaseous matter were obtained in the receiver.

* Annales de Chimie et de Physique, t. xlviii. p. 135.

* Turner's Chemistry, 8th edit. p. 1009.
† Annales de Chimie, t. xlix.

The tenth of a cubic inch of water being passed through the mercury, 8·5 cubic inches of the gas were absorbed by it. Solution of potash absorbed one-tenth of a cubic inch more, and the remainder consisted almost, or entirely, of air expelled from the retort.

c. Ten grains of chloroform were treated in the same way as before, the beak of the small retort communicating with two Woolfe's bottles, the first of which contained only thirty minims of distilled water, and the second some solution of nitrate of silver. A very slight cloudiness was merely produced in this solution in the second bottle. The water in the first bottle being added, at the end of the process, to a solution of nitrate of silver, and the precipitate occasioned being boiled in nitric acid, washed, and thoroughly dried, was found to weigh 11·45 grains.

If one of the three atoms of chlorine which were contained in the chloroform were to combine with the single atom of hydrogen, the hydrochloric acid thus produced from ten grains would weigh 3·04 grains, and would suffice to form 12·08 grains of chloride of silver. In experiment *a*, the chloride of silver obtained exceeded this by a very little. In experiment *b*, any chlorine which might be developed would be absorbed by the mercury, and the 8·5 cubic inches of gas absorbed by the small quantity of water must have consisted of hydrochloric acid. The weight of it would be 3·24 grains—a very little more than ought by theory to result from the combination of one of the atoms of chlorine with the hydrogen of the formyle; and it would combine to form 12·7 grains of chloride of silver. In experiment *c*, the thirty minims of water, whilst they absorbed the hydrochloric acid gas, could absorb but a very minute quantity of chlorine, certainly less than the tenth of a grain, and consequently if a greater amount of chlorine than this had been evolved it must have passed on to the second bottle, and there caused a precipitate of chloride of silver. On precipitating with nitrate of silver, it will be observed that the quantity of chloride obtained was very nearly that which ought to be formed by the hydrochloric acid produced as suggested above. These experiments, then, tend to show, that if chlorine be produced by passing the vapour of chloroform through a red-hot tube, it must be in extremely small quantity, and that consequently the proper tests to employ are those which indicate the presence of hydrochlorie acid.

The following is a brief account of the experiments for the detection of chloroform in the body:—

Exp. 55.—Two kittens about a fortnight old were placed in a glass jar holding 120 cubic inches. Twelve minims of chloroform were dropped on a piece of blotting paper in the jar, and it was closed. In two minutes the kittens were both insensible, and in two minutes more one of them had ceased to breathe; the other continued to breathe feebly and irregularly for six minutes longer. On the following day one of the kittens was opened: there was no odour of chloroform perceptible in this, any more than in the numerous other animals that I have killed with it.

a. The lungs, liver, and kidneys of this kitten were placed in a wide-mouthed glass flask with two or three drachms of water. The flask was placed in the water bath, to which (common salt not being at hand) was added a little chloride of calcium, to increase the temperature somewhat. A tube passing through the cork of the flask was connected with one of hard glass, which was kept red-hot in the flame of a spirit lamp, and to the end of the latter tube was attached one wetted inside with solution of nitrate of silver. About the time that the contents of the flask began to boil, a white curdy precipitate appeared in the latter tube. This precipitate was rendered dark-coloured by the light. It was insoluble in nitric acid, and very soluble in ammonia.

b. Two days after the death of the kittens, the lungs, heart, liver, and kidneys of the other animal were treated in a similar manner. Soon after the water in the flask began to boil, a precipitate of chloride of silver appeared in the tube.

c. Three days after their death, the brains of both kittens were put into a flask without any water, and heated in the chloride of calcium bath, as the other parts had been. On this occasion the tube moistened with solution of nitrate of silver ended in a Woolfe's bottle containing a few minims of the same solution. By the time that the liquid which had exuded from the brains began to boil, a precipitate began to appear in the tube, and in a short time there was one also, to a slight extent, in the bottle.

The brains were kept boiling in their own serosity for an hour. On the following day heat was again applied to the flask containing the brains which had not been removed; the tube and Woolfe's bottle having, however, been cleaned and supplied with a fresh solution of nitrate of silver. Not the slightest precipitate was obtained on this occasion, although the brains were kept boiling for two hours.

d. Five days after its death one of the kittens was skinned, and the flesh of the limbs, together with the greater part of that of the body and neck, was stripped off and put into the flask and treated as before, with the exception that, instead of the solution of nitrate of silver, a slip of paper moistened with a mixture of starch and solution of iodide of potassium was placed in the farther end of the tube. After the flesh had been made to boil for a little time in its own juice, a small part of the paper was turned blue.

e. Six days after its death the skin of the other kitten was removed, and its flesh put into a flask and treated as above; on this occasion, solution of nitrate of silver being used as the test. The serosity of the flesh had scarcely began to boil, when a precipitate of chloride of silver began to appear, and was soon as copious as on any previous occasion, both in the tube and Woolfe's bottle. At this time the intestines of the kittens were beginning to be offensive, although the flesh used in the experiment was not at all decomposed. The bodies had lain on a table since the time of death, at the beginning of last May, when the temperature was cool. From the size of the animals, the quantity of chloroform inhaled by each was considerably less than a grain.

To try the delicacy of the above process, a grain of chloroform was dissolved in a hundred drops of rectified spirit, and one drop of this solution was dropped into a flask containing a thousand grains of water. On treating this as above described, a distinct precipitate of chloride of silver was obtained in the tube, thus indicating the presence of the hundredth part of a grain of chloroform in a thousand grains of water.

Exp. 56.—On May 9, some portions of muscle, nearly sufficient to fill a three-ounce bottle, were taken from the calf of the leg of a little boy, about five years old, which had just been amputated by Mr. P. Hewett, under the influence of chloroform, in St. George's Hospital. About four hours afterwards the pieces of muscle were put into a flask, and treated as before described, solution of nitrate of silver being the test applied. When the liquid exuding from the muscle had been boiling for about ten minutes the precipitate began to appear, and was soon very distinct.

On July 2d, I assisted Dr. Taylor, in the Laboratory of Guy's Hospital, in applying this process to a little of the blood of a man whose death had been occasioned by chloroform, six days previously. The blood, which had been kept in a stoppered bottle, measured six and a half drachms, was of a dark red colour, fluid, but rather thick, and did not smell offensive. It was put into a clean Florence oil flask, from which a tube proceeded which was made red-hot, and a further tube moistened inside with solution of nitrate of silver. The flask was heated in the water bath, to which, after a time, common salt was added. The process was continued for twenty minutes or more, and although a slight cloudiness was observed in the tube, no distinct precipitate of chloride of silver was obtained. It should be remarked that this small quantity of blood must necessarily have been exposed to the air, before it was put into the bottle, by which means it would lose a part of its chloroform.

At the suggestion of Dr. Taylor, some chloroform (about 8 drops) was put into a flask with an ounce of water, and in the further tube were placed, first, a slip of starch paper moistened with solution of iodide of potassium; next, a slip of blue litmus paper, and the distal extremity of the tube was wetted inside with solution of nitrate of silver. The intermediate tube being made red-hot, as soon as heat was applied to the water bath, the two pieces of paper and the solution of nitrate of silver began to be affected, almost simultaneously: the starch paper being rapidly rendered very blue, the change of colour beginning at one end and travelling rapidly along it.

On the same occasion, in order to try the delicacy of these tests, a drop of chloroform, which is equal to the third of a grain, was agitated in a minim measure with fifty minims of alcohol. Five minims of this solution were added to an ounce of water in a flask, which

would consequently contain the thirtieth part of a grain of chloroform. A fresh tube being attached, containing the three tests before employed, and the flask being heated in the water bath, a decided effect was, in a little time, produced on all the tests. The starch paper was rendered blue; the litmus was turned red; and a very distinct precipitate was obtained in the solution of nitrate of silver.

Exp. 57.—July 13: Half a drachm of chloroform was diffused through a jar holding 670 cubic inches, and a kitten, weighing a little over thirteen ounces, was put in. In two minutes it was quite insensible, and at the end of ten minutes it died. On the 15th the kitten was opened, and the viscera of the chest, the liver, and the brain, weighing together nearly two ounces, were put into a flask and heated in the salt water bath. A tube coming from the flask was kept red-hot, and a further tube contained a slip of starch and iodide of potassium paper, and a slip of blue litmus, and terminated near the bottom of a Woolfe's bottle containing a few minims of solution of nitrate of silver. At the early part of the process, the edge of the starch paper seemed to be slightly changing colour, but after a little time no change of colour could again be observed in it. The blue litmus was very soon reddened, and the solution of nitrate of silver began to be turbid, and the turbidity increased for some time. The viscera were kept boiling in their serosity for half an hour.

On the following day other six ounces of the same kitten were put into the same flask; the intestines, skin, and larger bones being only left. Fresh starch paper was put into the tube which terminated in the bottle containing the same solution of nitrate of silver. After a little time the starch paper was decidedly darkened, at the corner nearest the flask, but only to a limited extent, which did not increase. The parts were kept boiling in their serosity for two hours, when the process was ended by the breaking of the tube at the part where it was red-hot, owing to a little condensed steam being projected against it. At the same moment the limited blueness of the starch paper was discharged. The tube being left lying on the table, it was found next day that the starch paper was very blue throughout its entire extent, from what cause I do not know. The precipitate of chloride of silver was separated by filtration, and but for an accident would have been dried and weighed. There appeared to be not less than the twentieth part of a grain of it.

There is no deposit of carbon in the red hot part of the tube in this process, as the apparatus always contains sufficient air for the formation of the carbon into carbonic acid. The white needle-formed crystals previously mentioned are deposited, but not in sufficient quantity to be of service as a test. It is desirable to make the tubes proceeding from the flask incline a little upwards, so that the vapour which is condensed before reaching the red-hot part may flow back again. I consider that the solid organs of the body should be taken for analysis, in preference to the blood in a separate state, as that contained in the minute vessels is protected from the action of the air. The parts should be cut in pieces, and put into the flask, without any addition. The stomach should not be selected for examination by the above process, as the gastric juice contains a minute quantity of free hydrochloric acid, and hence the evidence would be liable to objection. The intestines also do not seem suitable parts for examination, as the sulphuretted hydrogen they might contain would interfere, more or less, with the tests. In other respects it matters little what part of the body be used, further than that the most vascular parts are the best. As regards a quantitative analysis, it results from some of the experiments, detailed in an early part of these papers,* that, in a case of death from chloroform, a quarter of a pound of any organ of average vascularity would contain about the twelfth part of a grain, which, if the whole of it were separated and decomposed, would produce about the tenth of a grain of chloride of silver.

The process above described does not prove the presence of chloroform itself, but only that of a volatile compound containing chlorine. In this respect it resembles the processes for the detection of arsenious acid and corrosive sublimate in the tissues, which prove only the presence of a compound of arsenic, or of mercury. The only compounds containing chlorine which are volatile at

* Med. Gaz., vol. xlii. p. 415.

the heat of boiling water, are substances such as chloride of ethyle, Dutch liquid, and some others, which resemble chloroform in their effects, but are none of them in common use. In order to be quite certain that the precipitate is no other salt of silver than the chloride, besides the tests of ammonia and nitric acid, solution of potash might be added to another portion of it, as recommended by Dr. Taylor, in treating of hydrochloric acid.* Potash does not change the chloride of silver without heat.

With these limitations and precautions the process is, I believe, liable to no fallacy. There are chlorides in the body, but they cannot be decomposed, except at a high temperature, and not till the part under examination should become dry, which, in the method here described, could not take place in the most protracted examination. Besides, I have made several examinations of parts not containing chloroform without meeting with anything that produced the slightest effect on the nitrate of silver, or on the starch or litmus test. The bodies of two kittens killed with the vapour of ether were submitted to the process, by portions at a time, which were made to boil in their own serosity for an hour or two, but not the least effect was produced on any of these tests. Hearing, in the beginning of May last, that chloroform was suspected, by some of the coroner's jury, to have been used in the case of a woman who was found dead, under mysterious circumstances, in the Wandsworth Road, I applied to Mr. John Parrott, who was polite enough to send me some portions of the body, including part of the brain and liver. They had been kept in a covered jar from the time they were removed from the body. The chemical examination commenced four days after death, whilst the parts were fresh, and although very carefully conducted, not the least effect was produced, either on the nitrate of silver or starch and iodine test.

* Medical Jurisprudence, p. 91.

Part XV.

Detection of ether in the expired air after inhalation—Detection of alcohol in the expired air after it had been taken into the stomach—The effects of chloroform and ether protonged by causing the exhaled vapour to be re-inspired.

In my last communication it was shown that the vapour of chloroform can be detected by chemical tests, as it exhales from the blood in the expired air. The strong odour of ether, which continues to be perceived for hours in the breath of persons who have inhaled it, is a pretty good indication that this medicine is exhaled from the blood in a similar manner. I thought it desirable, however, to have a more material proof of the fact, than that afforded by the odour, and therefore contrived and performed the following experiments:—

Exp. 58.—As a preliminary measure I passed the expired air for twenty minutes through strong sulphuric acid, inspiring by the nostrils, and expiring by the mouth, through a spiral tube immersed in cold water; a continuation of this tube afterwards dipping into half an ounce of sulphuric acid contained in a bottle. The acid was afterwards boiled in a small retort, the beak of which communicated with a gas receiver under water. No gas was obtained beyond the air expelled from the retort by the heat, and the acid was not changed in colour.

Exp. 59.—On the following day—August 1st, I inhaled three fluid drachms of ether gradually, in the course of four minutes, and was rendered almost unconscious. After waiting for a minute, in order that the lungs might be entirely emptied of the vapour remaining at the conclusion of the inhalation, I commenced to pass the expired air through sulphuric acid, the air first passing through a spiral tube immersed in iced water, to condense the watery vapour, as in the last experiment. This process was continued for twenty minutes. A few hours afterwards the sulphuric acid was placed in a small retort, the beak of which communicated with a receiver under water, and was heated with the flame of a spirit lamp. It was gradually rendered quite black by the heat, and 11·3 cubic inches of gas were obtained in the jar. The jar being transferred to

the mercurial trough, and solution of caustic potash being introduced, the contents, after standing for an hour or two, and being agitated occasionally, till no further reduction of bulk would take place, were diminished to 3·9 cubic inches, showing an absorption of 7·4 cubic inches of carbonic acid gas. The jar being reversed, and a lighted taper being applied to its mouth, its remaining contents took fire, and burnt with a bluish flame. As 2·6 cubic inches of air were contained in the retort at the commencement of the process, the quantity of inflammable gas was probably 1·3 cubic inch.

Exp. 60.—On August 2nd, I again inhaled three fluid drachms of ether, and proceeded exactly as in the last experiment. The sulphuric acid was rendered black as before, and 7·6 cubic inches of gas were collected in the receiver. Potash absorbed 3·2 cubic inches of this, and the jar being reversed, and a lighted taper applied to its mouth, the remaining contents burnt with a flame which gradually descended in the jar to the surface of the mercury. Allowing for the air expelled from the retort, the quantity of combustible gas was 1·6 cubic inch.

Exp. 61.—In order to ascertain the nature of the inflammable gas produced, another experiment was performed, on a subsequent day. The same quantity of ether was inhaled, and the expired air was passed through sulphuric acid in the same manner. The acid was boiled in the retort, until 7·1 cubic inches of gas were obtained in the receiver, when the process was stopped. Solution of potassa being agitated in the gas absorbed 3·5 cubic inches. Two cubic inches of oxygen gas were added to the remaining 3·6 cubic inches, and a portion of the mixed gases was transferred to Dr. Ure's eudiometer. As it did not explode with the spark from a small electric machine, a small quantity of pure hydrogen gas was added, when explosion took place with the following result. The quantities are in hundredths of a cubic inch:—

Hydrogen	3·0
Oxygen, &c. . . .	21·0
Total	24·0
After explosion . .	16·5
Loss of volume . .	7·5

being a diminution of three parts more than the hydrogen would occasion. The remaining 16·5 parts were agitated with a little solution of potassa, when a further diminution of about six parts took place; a little more than ten parts being left. This result shows that the inflammable gas under examination was carbonic oxide, which, in becoming converted into an equal volume of carbonic acid, consumes half its own volume of oxygen. The beak and upper part of the small retort contained 1·9 cubic inch of air, which would be necessarily expelled into the gas receiver, and when this and the oxygen afterwards added are subtracted, the remainder is in the same proportion, very nearly, as the carbonic acid produced by the explosion; consequently the gases obtained by heating the sulphuric acid were carbonic acid gas, and carbonic oxide.

In these experiments, the ether passing off in the expired air is in part absorbed by the sulphuric acid, and on the application of heat is decomposed into various products; the above gases being given off, and free carbon remaining in the acid, and rendering it black. Sulphurous acid gas is evolved, but is absorbed by the water. On adding a few minims of ether to half an ounce of sulphuric acid, and operating in the same way as in the above experiments, the same products were obtained. Alcohol, when heated with a large excess of sulphuric acid, yields the same products as ether; but as I had taken no kind of fermented liquor before inhaling the ether in the above experiments, these products must have resulted from the sulphuric ether.

From the general resemblance between the action of alcohol, ether, and chloroform, and from these substances being governed in their action by some of the same general laws, as previously shown in the experiments on frogs and fishes,* it might be expected that since chloroform and ether can be shown to pass off in the expired air, alcohol would also be exhaled in the same manner. Common experience, so far as the sense of smell is concerned, is in accordance with this view. Leibig, however, says,† "according to all the observations hitherto made, neither the expired air, nor the

* Med. Gaz., last vol., p. 622.
† Animal Chemistry, p. 239.

urine, contains any trace of alcohol, after indulgence in spirituous liquors." This, so far as I know, was true as regards the human subject, but Dr. Percy* had obtained alcohol by distilling the urine of a dog, to which he had given a fatal dose of it.

Feeling a strong conviction that alcohol must pass off in the breath, I have made many experiments during the last twelvemonths, with a view to detect it. At first, I caused the expired air, after spirit had been drunk, to pass, for an hour or longer, through a spiral tube, immersed in ice and salt, but did not succeed in detecting alcohol in the condensed water. A little reflection, however, made it evident that alcohol could only exist there in extremely minute quantities; for the spirit which had been taken, being equivalent only to two ounces of absolute alcohol, the inspired air would only be able to take up about a two-hundredth part as much vapour of alcohol as would saturate it, at the heat of the body; and it would be in vain to attempt to reduce the air to such a low temperature as would cause it to deposit any part of so relatively small an amount of vapour; in other words, the alcoholic dew-point of the air must be lower than the temperature of the ice and salt, and, consequently, all the spirit that could be arrested would be that which might be attracted by the small quantity of condensed water. By collecting together the water condensed from the breath in six different experiments, I succeeded, however, in obtaining spirit in a pure state, as will be detailed further on.

In the following experiments the same method was employed, as detailed above, for the detection of ether.

Exp. 62.—August 6th, 1850. Two ounces and a half of rectified spirit of wine, of 80 per cent., were diluted with rather less than a pint of water, and taken, with bread and butter, at supper-time. A slight feeling of inebriation was occasioned by it, but not sufficient to interfere, in the least, with the proper performance of the experiment The air was afterwards taken in by the nostrils and breathed out by the mouth, through a wide tube communicating with a metal box containing a spiral arrangement, by which the air was obliged to pass round several times. This box was surrounded with ice. The air was conducted next, by a glass tube half an inch wide, to the bottom of a bottle containing half a fluid ounce of sulphuric acid. The object of condensing the moisture of the breath, in the metal box, was to prevent its diluting the sulphuric acid beyond the point at which it ceases to decompose alcohol when heated. The expired air was, in this manner, passed through the sulphuric acid for thirty-five minutes. Care was taken that no air coming from the stomach by eructation should pass into the apparatus. Two and a half fluid drachms of clear water were condensed in the metal box. The following morning, the sulphuric acid was put into a small retort, communicating with a gas receiver over water, and heated with the flame of a spirit lamp. The acid was rendered quite black, and 5·1 cubic inches of gas were obtained, of which 2·6 cubic inches consisted of air from the retort. The receiver being transferred to the mercurial trough, and a little solution of potassa introduced, 1·65 cubic inches were absorbed. The jar being inverted, and a light applied to its mouth, the remaining contents took fire, the flame gradually descending in the jar to the surface of the mercury. The quantity of inflammable gas was 0·85 cubic inch.

Exr. 63.—Another night the same quantity of rectified spirit was taken, in the same manner, and the expired air passed through the spiral box and the sulphuric acid as before. Six fluid drachms of acid were employed this time, and the process of breathing through it was continued for an hour. Two and a half drachms of water were again condensed in the metal box, and the acid was increased in bulk by rather more than half a drachm. The sulphuric acid was next morning placed in a retort and heated. It was turned black, and six cubic inches of gas were obtained, two of which consisted of air from the retort. Solution of potassa absorbed 3·45 cubic inches of carbonic acid gas, and the remaining contents of the receiver burnt with a slight explosion, on a light being applied. The inflammable gas did not amount to more than 0·55 cubic inch.

Exp. 64.—The same quantity of rectified spirit was taken at night on another occasion, and the expired air passed for an hour through sulphuric acid in

* Prize Thesis "On the Presence of Alcohol in the Brain," &c.

the same way as before. The quantity of acid employed this time was a fluid ounce. On the following morning six drachms of the acid were heated in a small retort: they were rendered quite black, and somewhat viscid. 4·85 cubic inches of gas were obtained in the receiver, of which 1·8 cubic inch consisted of air from the retort; potash absorbed 0·6 cubic inch; 0·85 cubic inch of the remainder was transferred into a small jar, to the mouth of which a taper was applied, when the contents burnt for a little time with a bluish flame. To the residue in the receiver 3·8 cubic inches of oxygen were added, and a portion of the mixture was introduced into the eudiometer. As it did not explode with the electric spark, a small quantity of pure hydrogen gas was added, when an explosion was effected with the following result:—

Hydrogen	3·0
Oxygen, &c. . . .	32·0
Total	35·0
After explosion . .	27·0
Diminution	8·0

being a loss of 3·5 more than occasioned by the hydrogen.

Solution of potassa being agitated in the remaining 27 parts, they were diminished to 19; showing an absorption of 8 parts of carbonic acid. The loss of volume was consequently very nearly half as great as the quantity of carbonic acid gas produced by the explosion; and therefore the inflammable gas under examination was carbonic oxide, the amount of which was just one-fourth of the mixed gas introduced into the eudiometer. It is evident on calculation that nearly 1·8 cubic inch of carbonic oxide must have been expelled from the retort, and that this and the carbonic acid were the only gases evolved by the sulphuric acid.

The decomposition which the alcohol, absorbed from the expired air, undergoes in the sulphuric acid is the same as that undergone by the ether in the experiments previously detailed.

Exp. 65.—The water condensed in the metal box, surrounded with ice in the above three experiments, and in three others not related, amounted together to two ounces. It was placed in a retort, and about three drachms were distilled. This product was placed in a smaller retort, and about twenty minims were distilled into a small test tube. Dry carbonate of potassa was added to this till it would dissolve no more. In a little time, a layer of clear spirit, about the tenth of an inch in thickness, floated on the top of the solution of potash. A piece of asbestos being dipped in this, it burnt with a blue flame. A very little powdered camphor was dropped into a small tube, drawn at one end to a capillary point. This point being brought in contact with the liquid floating on the solution of potash, a little of it rose by capillary attraction, and was observed to dissolve the camphor within. On blowing at the other end of the tube, a minute drop of solution of camphor was forced out, and received on a piece of glass, when the spirit immediately evaporated, leaving a coating of camphor. These tests leave no doubt of the presence of alcohol. The process used in this experiment is similar to that employed by Dr. Percy for the detection of alcohol in the brain and other organs.

Exp. 66.—Two and a half fluid ounces of rectified spirit, of 80 per cent., were diluted with water, and taken at suppertime. The air was afterwards inspired for fifty minutes by the nostrils, and expired by the mouth, through a glass tube which dipped into three ounces of water contained in a bottle. Next morning the water was put into a retort, and about three drachms were distilled, which were put into a smaller retort, and about twenty minims were distilled into a small test tube. On carbonate of potassa being added in excess, a thin layer of clear liquid floated on the surface. This was proved to be alcohol; for a little bit of asbestos being moistened in it, burnt with a blue flame, and it dissolved camphor in the way described in the former experiment.

Whilst the above experiments show that alcohol is exhaled in the breath after it has been taken into the stomach, a little consideration will prove that only a small part of it can be excreted in this manner. When there are two ounces of alcohol in the blood, the air which reaches the lungs can only take up, as stated before, about a two-hundredth part as much as would saturate it at the temperature of the blood. At this rate, a person breathing the usual amount of air would only exhale about twelve minims of alcohol in an hour;

consequently, if it had to pass off entirely in the expired air, its effects would continue for a very much longer period than they do; and, since alcohol can hardly be detected in the other excretions, it must be decomposed in the system into fresh products.

I have assumed from the first that the speedy subsidence of the narcotism caused by chloroform and ether, in comparison with that from alcohol and other narcotics, depends on the volatility of the former substances, which allows of their ready exit by the expired air. Indeed, the effects of these medicines usually subside in the period which a calculation founded on this view would assign to them. It was previously estimated, for instance, that twenty-four minims of chloroform are contained in the blood of an adult of average size in a state of very complete insensibility; this being about one-twenty-eighth part as much as the blood would dissolve. The inhalation being now discontinued, the fresh air which reaches the air cells will abstract from the blood nearly one-twenty-eighth part as much as it can hold in suspension at the temperature of 100°; and as each hundred cubic inches of air, when saturated at 100°, contains 43·3 cubic inches of vapour of chloroform, $43\,3 \div 28 = 1{\cdot}54$ cubic inches, or 1·48 minims, will be the quantity removed by the first hundred cubic inches of air which reaches the air-cells. It has been shown that about half the inspired air gets as far as the air-cells; and, supposing the patient to be breathing 400 cubic inches in the minute, 200 cubic inches would act in the removal of the vapour. In this manner it would take two minutes and a half to reduce the quantity of chloroform from 24 to 18 minims, and the narcotism from the fourth to the third degree; after which the effects would diminish more slowly, and in three and a half minutes longer the narcotism would have diminished to the second degree. Then, as the air would only take up about one-fifty-sixth part as much as it would hold, in about five minutes longer we might expect the return of consciousness; and the slight dizziness or confusion which might remain would subside still more gradually. The above statement expresses pretty well what usually occurs when the inhalation has been kept up for a little time. Children recover from the effects of chloroform more rapidly, on account of their quicker circulation and respiration. Old people, on the other hand, more slowly, for the opposite reason. When insensibility is produced in the course of two minutes for a short operation, and the inhalation is not repeated, the effects of the vapour subside more quickly than stated above; because, at the same time that the chloroform is passing off by the lungs, it is also escaping from the main current of the circulation, by permeating the coats of the small vessels, and diffusing itself in the tissues, and thus allowing the brain to resume its functions.

Ether is more volatile than chloroform; but being also much more soluble, the relative quantity absorbed into the system is so much greater, as to more than compensate for the superior volatility; and consequently the effects of ether subside somewhat more slowly than those of chloroform, the ether taking rather longer to pass off in the expired air.

It follows as a necessary consequence of this mode of excretion of a vapour, that, if its exhalation by the breath could in any way be stopped, its narcotic effects ought to be much prolonged. The following experiments show that such is the case:—

Exp. 67.—About 750 cubic inches of oxygen gas were introduced into a balloon of thin membrane, varnished with solution of Indian rubber in turpentine. The balloon was attached to one of the apertures of the spiral box which forms part of the ether inhaler I employ, and which was used for condensing the moisture in the experiments on alcohol previously detailed. Four ounces of solution of potassa were put into the inhaler, and to its other opening was attached a tube, connected with a face-piece without valves.* After inhaling as much chloroform as I could without being rendered unconscious, I immediately began to breathe the oxygen from and to the balloon, and over the solution of potassa. In this way the vapour exhaled in the breath had, the greater part of it, to be re-inspired. This process was continued for ten

* I used the same arrangement in giving oxygen gas last year, at the request of Dr. Wilson, to a cholera patient in St. George's Hospital. The patient, who was in a state of collapse, was not saved or relieved by it.

minutes, during which time the feeling of narcotism subsided very little, and it passed off very slowly afterwards, about half an hour elapsing before it was quite gone.

The oxygen was used, in this and the following experiments, to allow of respiration being continued for some time from the balloon without employing such an amount of air as would take up a great deal of the vapour. As there was air both in the lungs and inhaler at the beginning of the experiment, the oxygen was not breathed unmixed with nitrogen. The solution of caustic potash was employed for the purpose of absorbing the carbonic acid gas generated by respiration as the air passed to and fro over a large extent of its surface.

Exp. 68.—On another day the same quantity of oxygen and solution of potassa were employed, and fifteen minims of chloroform were placed in the spiral inhaler, in a small glass vessel, which prevented its mixing with the solution of potassa. I then began to breathe as in the former experiment, and continued to do so for fifteen minutes. The effects of the chloroform were gradually induced during the first three minutes, causing a considerable feeling of narcotism, but not producing unconsciousness. After the end of three minutes, the feeling of narcotism remained stationary till twelve minutes had elapsed, and during the last three minutes it very slightly diminished. The experiment was discontinued on account of a feeling of want of breath. It was half an hour longer before the effects of the chloroform were altogether removed.

Exp. 69.—The oxygen and solution of potassa were employed as before, and two and a half fluid drachms of ether were put into the inhaler, with the potash. The oxygen was breathed to and fro over the potash for twenty minutes. The effects of the ether were rapidly developed during the first three minutes, but not amounting to loss of consciousness. From this time, the influence of the ether remained nearly the same to the end of the experiment, and afterwards subsided very gradually.

The effects of the small quantity of chloroform and ether inhaled in these experiments would have passed off in three or four minutes, if the exhaled vapour had been allowed to diffuse itself in the air in the usual way.

The amount of carbonic acid absorbed by the potassa was determined, and will be given in the next communication, as it forms a separate branch of the inquiry into the action of narcotic vapours.

Part XVI.

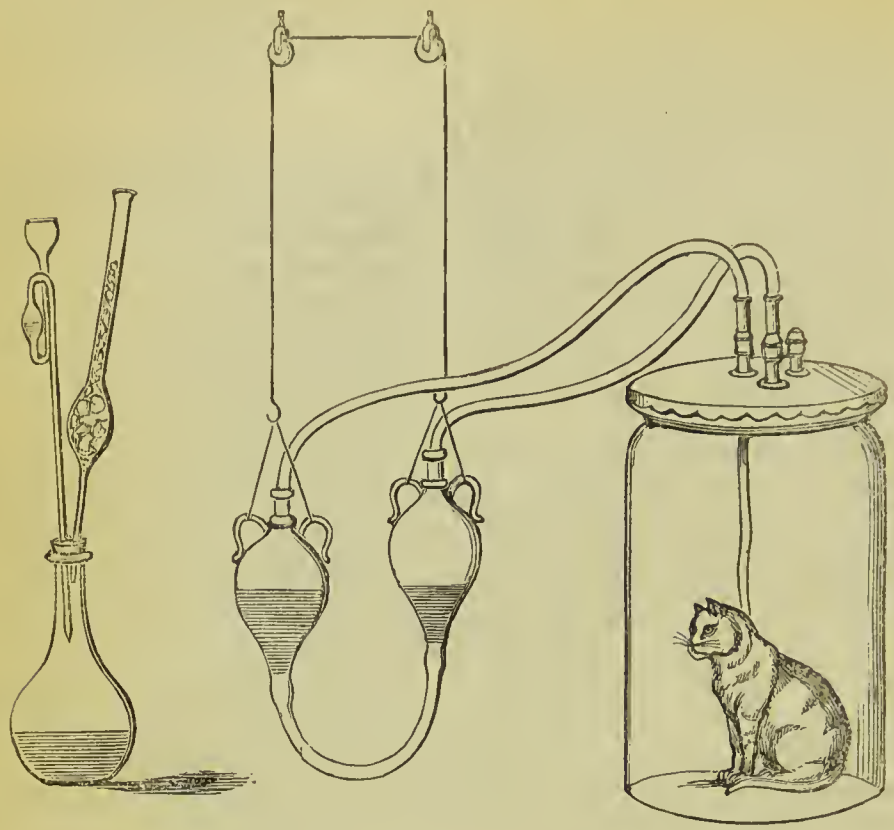
Experiments to determine the amount of Carbonic Acid Gas excreted under the influence of Chloroform—of Ether.—Diminution of Carbonic Acid caused by Alcohol.—Chloroform, Ether, &c., produce their effects by diminishing Oxidation in the system, without necessarily *combining with oxygen themselves.—Proofs of this view.*

In order to ascertain with accuracy the quantity of carbonic acid gas excreted by animals whilst under the influence of chloroform and ether, I employ some apparatus similar to part of that used by MM. V. Regnault and J. Reiset in their chemical researches on the respiration of animals.*

The accompanying engraving will assist to give a correct idea of the apparatus. The animal to be experimented on having been placed in a large glass jar, the latter is covered with a lid, padded on its under surface with an India rubber cushion, to make it fit accurately. In this lid there are three apertures. One of them serves for introducing the chloroform or ether, and can be closed by a brass mount; the others are connected, by means of tubes of vulcanized India rubber, to a potash apparatus, consisting of two glass vessels with an opening at each end, connected together at the lower part by means of another elastic tube. The solution of potash employed is diluted with sufficient pure water to make it fill one of the vessels; and as these vessels are made to move up and down during the experiment, by means of a cord passing over pullies, the solution of potassa is moved alternately from one vessel to the other, its place being occupied by air from the jar, which is returned back again as the vessel descends and becomes again filled with the liquid. As the tube from one of the potash vessels is continuous with

* Annales de Chimie et de Physique, 1849.

one which descends nearly to the bottom of the jar containing the animal subjected to experiment, air is alternately withdrawn and returned at its upper and lower part. A constant circulation of air thus takes place, and the carbonic acid gas becomes absorbed soon after it is given off from the lungs.



To determine the quantity of carbonic acid gas taken up by the solution of potassa, it is first put into a flask and boiled, to expel the chloroform or ether it may have absorbed. The flask is afterwards closed with a stopper, perforated for the admission of a safety tube, and a tube containing chloride of calcium.* The whole is then carefully weighed, together with a bottle containing rather more dilute sulphuric acid than is sufficient to saturate the solution of potassa. The acid is introduced gradually through the safety tube, and the contents of the flask heated to the boiling point, in order to expel the whole of the carbonic acid gas from the liquid. By making aspiration through the chloride of calcium tube, the whole of the carbonic acid is removed from the flask, its place becoming occupied by fresh atmospheric air, which enters through the other tube. When the contents of the flask have cooled to the temperature at which the previous weighing took place, the apparatus is again carefully weighed, and the loss of weight shows the quantity of dry carbonic gas expelled. On deducting from this the small quantity of carbonic acid known to have been contained in the solution of potassa employed, the remainder shows the quantity which has been absorbed by it during the experiment.

Exp. 70.—On December 18th, 1850, a rabbit, weighing four pounds, was placed in a jar holding 1,600 cubic inches, and allowed to remain for half an hour, the potash apparatus above described being kept in motion during this time. The rabbit was very quiet during this part of the experiment.

The potash vessels having been emptied and replenished, and the rabbit having been removed for a few minutes for the ventilation of the jar, it was put in again, and twenty-five grains of chloroform were introduced through the

* See figure at the left side of the engraving.

aperture in the cover. The vessels containing the solution of potassa were kept moving up and down, as before. The rabbit moved about briskly on the introduction of the chloroform, and continued to do so for six minutes, after which it lay apparently asleep, but started spontaneously, now and then, as if in a disturbed dream. On its removal it showed signs of sensibility when touched, but appeared quite unconscious.

After being out of the jar for five minutes, and the jar having been well ventilated in the meantime, the rabbit was put in again, in much the same state as when removed. It remained for half an hour, sleeping the greater part of the time, but had almost recovered from the effects of the chloroform on its removal. The potash apparatus was in action as before.

The solution of potassa employed in the different parts of the experiment was analysed, with the precautions before described, and gave the following results:—

The quantity of carbonic acid gas absorbed in the first part of the experiment, before the exhibition of chloroform, was 6·80 grains. In the second part of the experiment, during the inhalation of chloroform, 2·78 grains were absorbed; and 2·85 grains after the inhalation, whilst the rabbit was gradually recovering.

Exp. 71.—On December 21st, 1850, a young dog, weighing eight pounds, was placed in the jar holding 1,600 cubic inches, and allowed to remain half an hour, the potash apparatus being kept moving, as in the previous experiment. The dog whined and turned round occasionally, but did not make much muscular effort.

The dog having been removed for a few minutes in order to ventilate the jar, was put in again, and twenty-five minims (thirty six grains) of chloroform were introduced. The potash apparatus, which had been replenished, was moved up and down as before. On the introduction of the chloroform the dog made violent efforts to escape, and his muscular exertions continued, when they were no longer directed by consciousness, till he sank down apparently insensible at the end of about eight minutes. The head and limbs, however, continued to be moved occasionally during the remainder of the half hour. On his removal from the jar the dog yelped, but his muscles were quite flaccid, and he lay for a time where he was placed, and afterwards recovered gradually.

The solution of potassa employed in the half hour just before the chloroform, was found to have absorbed 10·1 grains of carbonic acid gas, whilst that employed for the same period with the chloroform had absorbed only 4·8 grains.

Exp. 72.—On January 19, 1851, a cat about half-grown was placed in a jar holding 920 cubic inches, and allowed to remain for half an hour whilst the potash apparatus was in operation, as in the other experiments. The cat made occasional efforts to get out of the jar.

A few minutes after its removal from the jar, the cat was put in again, and twenty grains of chloroform were introduced through the aperture in the cover. The potash apparatus, having been replenished, was kept in motion, as before. On the introduction of the chloroform the cat made violent efforts to get out. In two or three minutes it became unconscious; but it continued to move involuntarily until five minutes had elapsed, when it sank down in a state of insensibility. During the remaining twenty-five minutes of the experiment the breathing was quick, and much deeper than natural. The cat was quite insensible to pricking and pinching on its removal.

The solution of potassa employed just before the chloroform was given absorbed 5·7 grains of carbonic acid gas; whilst that used during the time that the chloroform was exhibited, absorbed but 2·0 grains.

Exp. 73.—On Feb. 17, 1851, a cat weighing four pounds and a half was placed in the jar holding 1600 cubic inches, and kept there for half an hour. It sat very quietly the whole time. A few minutes afterwards it was put into the same jar again, and eighteen grains of chloroform were introduced by the aperture in the lid. The cat moved about somewhat during the first seven or eight minutes, but it lay sleeping the remainder of the half-hour: it was not insensible on its removal, but inclined to sleep when not disturbed. The cat, having been removed for a few minutes to ventilate the jar, was put in again, and twenty-seven grains of chloroform were introduced. The cat had in a great measure recovered from the

effects of the former dose of chloroform during its removal: it attempted to escape on the fresh chloroform being introduced, but soon became quiet and apparently insensible. At the end of half an hour the solution of potassa was changed, without removing the animal from the jar. Chloroform was now added by ten minims at a time, about every ten minutes, till the cat was killed. It died very gradually at the end of three-quarters of an hour. The breathing became very feeble, and intermitted, for long intervals before death took place, and there were no gaspings.

The potash apparatus was in operation during the experiment, and the analysis of the solution of potass gave the following results:—

Carbonic acid gas excreted in half an hour, just before the chloroform, 7·7 grains.

In half an hour, with eighteen grains of chloroform in the jar, 5·7 grains.

In the same time, with twenty-seven grains of chloroform, 4·9 grains.

During the last three-quarters of an hour, 7·1 grains, which is at the rate of 4·7 grains for half an hour.

It will be observed that the quantity of carbonic acid gas excreted under the influence of chloroform was considerably less in all the above experiments than it had been just before; and, in the last experiment, it will be remarked that the excretion of carbonic acid kept diminishing as the narcotism increased; whilst in Exp. 70 it increased somewhat during the last stage of the experiment, whilst the effects of the chloroform were subsiding.

It would not be easy to make correct experiments for ascertaining the amount of carbonic acid gas excreted by patients whilst under the influence of chloroform; and my inquiries on this point in the human subject have been confined to such experiments as I could conduct on myself whilst slightly affected by the vapour.

In two experiments related in the last part of this series of papers,* in which oxygen gas was breathed to and fro over solution of potassa, whilst under the partial influence of chloroform, the amount of carbonic acid absorbed by the potash was determined in the manner described above, for comparison with that absorbed in experiments conducted in a similar manner a little time before the chloroform was inhaled. The quantity of carbonic acid was diminished by the chloroform, as is shown in the following table:—In Exp. 67, for instance, 42 grains of carbonic acid gas were absorbed by the potash whilst breathing oxygen for ten minutes, before the chloroform had been inhaled, and only 33 grains during the same period, just after the inhalation of chloroform. A similar diminution of the amount of carbonic acid took place in Exp. 68.

In the subsequent experiments enumerated in the table, the air was inspired by the nostrils and expired by the mouth, through a glass tube which conveyed it through a solution of potassa placed in two Woulfe's bottles. The ex-

No. of Exp.	Date of Exp.	Duration of Exp.		Carbonic Acid.		Carb. Acid per min.	
		Before Chlorm.	With Chlorm.	Before Chlorm.	With Chlorm.	Before Chlorm.	With Chlorm.
67	Sep. 3, 1850.	10 min.	10 min.	42·0 grs.	33·0 grs.	4·20 grs.	3·30 grs.
68	Sep. 19, „	15 „	15 „	73·0 „	46·0 „	4·86 „	3·06 „
74	Oct. 28, „	10 „	10 „	23·0 „	20·5 „	23.0 „	2·05 „
75	Oct. 30, „	20 „	20 „	57·0 „	53·0 „	2·85 „	2·65 „
76	Oct. 31, „	15 „	15 „	42·0 „	36·5 „	2·80 „	2·43 „
77	Mar. 18, 1851.	20 „	20 „	43·0 „	37·5 „	2·17 „	1·87 „
	Mean quantity of carbonic acid per minute.					3·19 grs.	2·56 grs.

* Medical Gazette, last vol. p. 753.

periments were made at ten or eleven o'clock in the evening, after sitting quietly for two or three hours. The breath was passed through the solution of potassa before inhaling, and then through a similar solution, after inhaling as much chloroform, for three or four minutes, as could be taken without causing unconsciousness. An inspiration of chloroform was also taken, now and then, during the remainder of the experiment, to prevent the effects of the vapour from altogether subsiding.

Soon after the introduction of the inhalation of ether, I made some observations on the amount of carbonic acid gas exhaled from the lungs under its influence, by passing the expired air through lime water, when I found the quantity to be diminished.* The following more recent experiments on animals have been attended with a similar result.

Exp. 78.—On Dec. 15, 1850, a rabbit, weighing four pounds, was kept in a jar, of the capacity of 1600 cubic inches, for forty minutes, the potash apparatus, before described, being in motion all the time. The rabbit was perfectly quiet. Soon afterwards, the rabbit was put into the jar again, and forty grains of ether were introduced, which did not cause insensibility, but only inebriation. The rabbit remained in a position between sitting and lying, being able to hold its head up. It was removed at the end of forty minutes.

Twenty minutes after its removal, when the effects of the ether had almost altogether gone off, the rabbit was a third time placed in the jar, for the space of forty minutes.

The analysis of the potash employed in the first part of the experiment, before the ether, yielded 12·6 grains of carbonic acid The carbonic acid given off during the inhalation of ether was not correctly determined, owing to an accident ; but that employed in the third part of the experiments yielded 10·8 grains, showing a notable diminution, although the effects of the ether on the animal had almost ceased to be perceptible

Exp. 79.—In March, 1851, two pigeons were placed for twenty minutes in a jar holding 670 cubic inches. They stood still the whole time. A few minutes after their removal they were put into the jar again, and sixty grains of ether were introduced, at short intervals, by a few grains at a time. The pigeons became gradually insensible, and at the end of eight minutes were lying on the side. They showed no signs of sensibility when removed at the end of twenty minutes, but lay where they were placed. After being out for three minutes, they were put into the jar again, as they were beginning to evince signs of returning sensibility. In ten minutes more they were able to stand, but they were not fully recovered, when they were removed, at the end of twenty minutes.

The potash apparatus was in action, as in the previous experiments. The solution of potassa employed in the first part of the experiment absorbed 6·1 grains of carbonic acid; that employed in the second part absorbed 3·6 grains ; and that employed in the last part of the experiment, whilst the effects of the ether were subsiding, absorbed 4·4 grains.

The late Dr. Prout discovered, nearly forty years ago, that fermented and spirituous liquors diminish the amount of carbonic acid given off from the lungs. He summed up the result of his experiments on this point in the following words :—"Alcohol, in every state, and in every quantity, uniformly lessens, in a greater or less degree, the quantity of carbonic acid gas elicited, according to the quantity and circumstances under which it is taken."* Dr. Prout's experiments were confined to the proportion of carbonic acid gas in the expired air. A recent German author has extended his inquiries to the quantity exhaled in a given time, and he finds that both the proportions in the expired air and the quantity excreted per minute are diminished during the action of alcohol. He also finds that the total amount of every one of the constituents of the urine is lessened, under the same circumstances.†

The diminution of the amount of carbonic acid formed in the system

* See Report of Westminster Med. Soc. in Med. Gaz., Feb. 26, 1847.

* Ann. Phil. vol. ii. p. 336.

† Beiträge zur Heilkunde nach eigenen Untersuchungen von Friedr. Wilh. Böcker. Crefeld, 1849. I am indebted to the kindness of Dr. Bence Jones for the knowledge of this work.

under the influence of chloroform, ether, and alcohol, taken in conjunction with a circumstance shown in a former paper, that the chloroform and ether are exhaled unchanged from the blood, assist to prove a view of their modus operandi which I suggested with respect to ether, early in 1847.* That view may be stated as follows.

Chloroform, ether, and similar substances, when present in the blood in certain quantities, have the effect of limiting those combinations between the oxygen of the arterial blood and the tissues of the body which are essential to sensation, volition, and, in short, all the animal functions. The substances modify, and in larger quantities arrest, the animal functions, in the same way, and by the same power, that they modify and arrest combustion, the slow oxidation of phosphorus, and other kinds of oxidation unconnected with the living body, when they are mixed in certain quantities with the atmospheric air.

This explanation is probably applicable to the action of all narcotics whatever, but is here applied only to the class considered in these papers, namely, the volatile narcotic substances not containing nitrogen, or those substances whose power was found to be in the inverse ratio of their solubility in water and the serum of the blood.

The circumstances which appear to my mind fully to establish the above stated theory of the operation of chloroform and similar bodies, are enumerated in the following propositions :—

1. Sensation, motion, thought, and indeed all the strictly animal functions, are as closely connected with certain processes of oxidation going on in the body, as the light and heat of flame are connected with the oxidation of the burning materials.

2. The diminution of the amount of carbonic acid gas excreted by the lungs under the influence of chloroform, ether, and alcohol, shows that the processes of oxidation going on in the body are lessened, for the amount of carbonic acid given off has a pretty close relation to the quantity of oyxgen consumed.

3. The diminution of temperature in animals under the influence of chloroform and ether, alluded to in an early part of these papers, also shows that the processes of oxidation which take place in the body are diminished, since the development of animal heat has been shown, by Edwards and others, to have a constant relation to the quantity of oxygen which is consumed in respiration.

4. The venous blood in patients under the influence of chloroform or ether is less dark in colour than in the normal state; indicating that those changes in the blood which take place in the systemic capillary circulation are diminished.

5. The lessened quantity of all the constituents of the urine, observed by Böcker, from the effects of alcohol, also shows that oxidation is diminished.

6. The diminished oxidation is not owing to the combination of the narcotic substance with the oxygen of the arterial blood; for in the first place, the chloroform and ether, as well as part of the alcohol, have been shown to escape unaltered in the breath; in the second place, the quantity of material, in the case of chloroform, capable of combining with oxygen, is altogether insufficient so to appropriate the oxygen; and in the third place, to increase the amount of oxygen in the respired air does not prevent the action of the narcotics.

7. The different parts of the nervous system lose their power under the influence of the narcotics we are considering, in the same order as in asphyxia—the privation of oxygen, as was observed by M. Flourens with respect to ether, in 1847.*

8. The muscular irritability, which continues for a short time after death, depends on the action of a little oxygen still remaining in the system; and this irritability can be at once extinguished by chloroform, ether, or alcohol, in proportion rather larger than is necessary to cause death. When the muscular irritability is thus extinguished, post-mortem rigidity comes on almost immediately, and lasts for an unusually long time, if the narcotic employed is prevented from evaporating.

9. The vapours of volatile narcotic substances have the property, when mixed with the air, of retarding, and, in larger quantity, of arresting, that form of oxidation which constitutes ordinary

* See MED. GAZ. vol. xxxix. p. 383.

* Gazette des Hôpitaux, 20 Mars, 1847.

combustion; and their power in preventing combustion generally bears a direct relation to their narcotic strength.

10. Many of these same vapours have the property of preventing the slow oxidation of phosphorus, which renders it luminous in the dark, as was discovered by Prof. Graham; and their effects, in this respect, have a general relation to their narcotic power.

11. The putrefaction of animal substances consists, on its commencement at least, of a process of oxidation; and the numerous class of substances we are considering all have the property of preventing putrefaction, their antiseptic power having generally a direct relation to their narcotic properties.

12. The reduction of the temperature of the body, by exposure to cold, diminishes the consumption of oxygen, and causes symptoms very nearly resembling the effects of a narcotic.

The second and sixth of the above propositions have already been fully considered, and the remainder will receive further consideration in my next paper.